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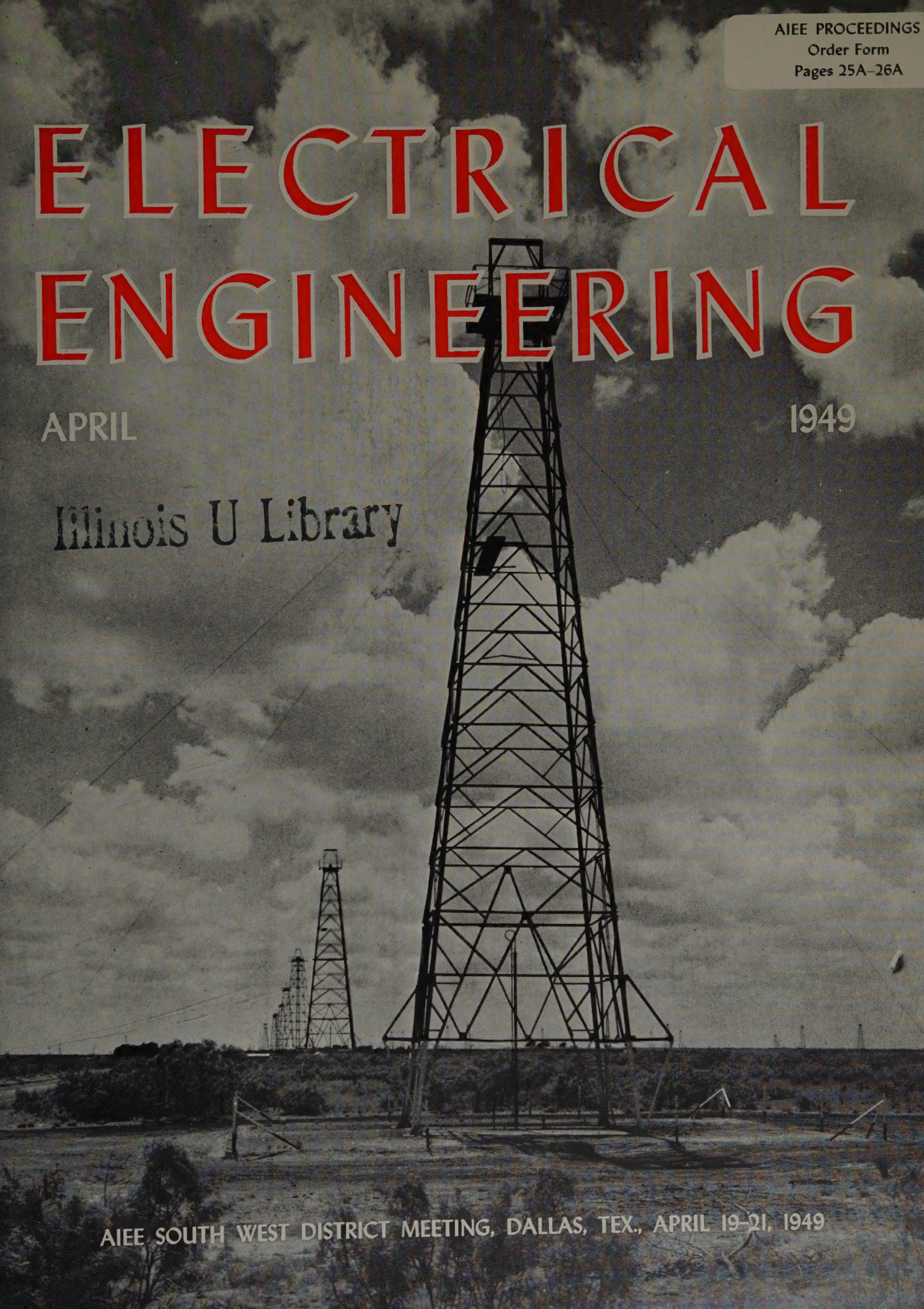

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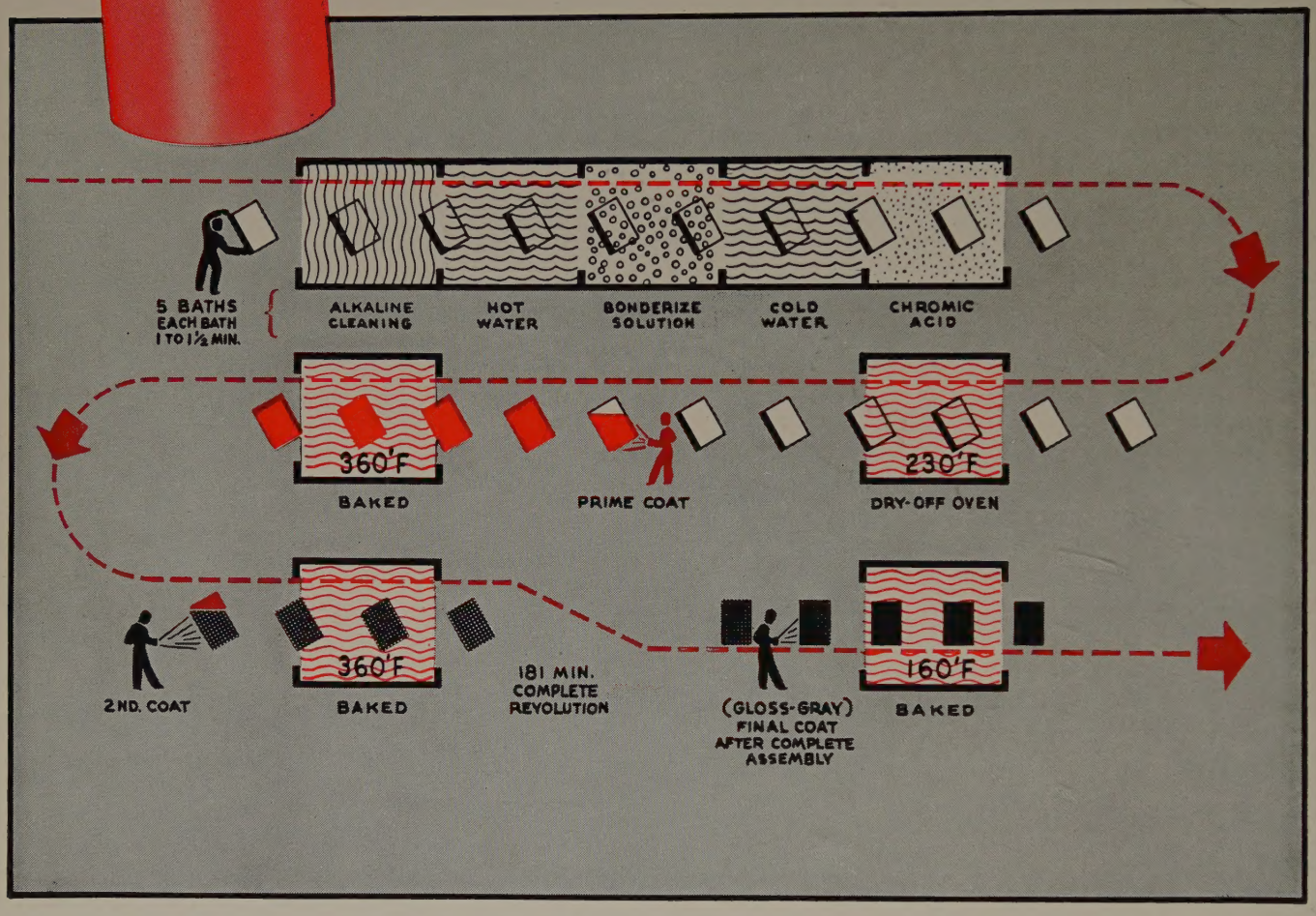

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Co-operative Education at the Undergraduate Level

E. M. STRONG
MEMBER AIEE

Co-operative education has proved to be a major element in preparing engineering students for their professional careers. In essence, it is a plan whereby students alternate periods of study in school with periods of activity in industry. Recent developments in operation indicate even greater interest, and consequently new work areas, for the future.

AT THE TURN of the century, what is variously termed the co-operative "plan," "system," or "program" was instituted in engineering at the University of Cincinnati by Dean Herman Schneider.[1] Simply described, it is a planned program whereby students are assigned alternately to study in school and to activity in industry. The periods of alternation usually are about equal and at first were but one week long. These soon were extended to two, four, and eventually seven weeks at the University of Cincinnati. With spread of the plan to other schools, even longer periods have been successful, and in some cases periods in school and industry are made unequal. Co-operative education today is a large-scale operation confined neither to the undergraduate level nor to engineering.

OBJECTIVES

The objectives of the co-operative plan in 1946 were formulated with some care and authority by a special committee of the American Society for Engineering Education appointed for the purpose by the co-operative engineering education division of the society.[2] Anyone seriously interested should not fail to study this report and the ample bibliography appended thereto.

Specifically identified with the co-operative activity, the report lists five purposes as follows:

1. To impart first-hand and actual knowledge of and experience with the execution in industry of engineering designs, projects, and developments.
2. To impart understanding of and familiarity with the problems and the viewpoints of working men and women.
3. To assist students, by direct and personal experience in industry, to test their aptitude for engineering careers.
4. To enable engineering students to adjust themselves to engineering employments by gradual and easy transition from academic pursuits and mode of life to the requirements and conditions of industry.
5. To train and otherwise prepare students especially and directly for the administrative and operating functions which, to a greater or lesser degree, enter into most engineering careers.

Laboratories, visual aids, speakers from industry, and so forth, fail to provide for the student on campus the equivalent of his personal contact with industry.

Over the years the co-operative plan often has been identified with an economic objective: "Earn while you learn." There is some reason to believe that this is founded not only on student interpretation or popular hearsay. Nevertheless, it is the stated purpose of the schools represented in the ASEE report that the primary objective emphatically is an educative one rather than a financial one.

It seems clear that some care in organization and operation is requisite to insure that the educative objective may not fade from factual operation to wishful ideal. The danger is minimized by:

1. Competitive selection of students for the co-operative plan, including scrutiny of individual motives.
2. General avoidance of assignment of student to a job near home.
3. Uniform pay rates commensurate with co-operative objectives.

BENEFITS

As just outlined, the first purpose of the co-operative plan is to benefit the individual student directly by providing for him in industry an essential educative opportunity unavailable in a campus-confined curriculum.

Not to be ignored, however, are less direct benefits to the school, the staff, the industry and the non-co-operative students where the school is not operating 100 per cent co-operative.

(*a*). The school, through enriched industrial contacts, facilitates flow of up-to-date information and equipment from industry.

(*b*). The teacher not only benefits by the foregoing but is encouraged especially by co-operative students in his classes to keep his teaching up-to-date and to the point.

(*c*). Industry benefits not only from the immediate contribution of the co-operative employee but more certainly, perhaps, by a favorable opportunity for recruiting pretested graduates of high promise who will continue successfully with the company. Although it is a cardinal principle of co-operative operation that no obligation, real or implied, exists between student and industry for employment after graduation, when they do get together, prolonged satisfaction for both is highly probable.

ORGANIZATION

The key administrative element in co-operative operation usually is termed the "co-ordinator." A member of the school staff, he is a combination of placement bureau, job supervisor, student counsellor, labor mediator, schedule gymnast, curriculum builder, and teacher—in short, either he is a top-notch educator or the co-operative fails of its

Full text of a conference paper presented during the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949.

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objectives. The extent of his identification with general student placement, and direct teaching, as well as with co-operative operation depends, of course, upon the size of the school and its co-operative program. The all-co-operative school generally requires not one co-ordinator but a staff of co-ordinators, and possibly a dean of co-operative education.

More than may appear at first, it is essential that the administrative and teaching staffs of the school actively favor the co-operative plan and support the co-ordinator in his work with student and facutly. This perhaps is felt more acutely where the school operates only part of its program co-operatively; an all-co-operative school presumably attracts few faculty not sold on the co-operative plan.

Second only to the importance of the co-ordinator, are two industrial elements—the industrial personnel responsible for policy concerning co-operatives and those to whom the student is directly responsible. Any deficiency in either the ability or enthusiasm of these for the co-operative operation endangers its success in that industry, and to some extent affects the over-all operation.

It is essential that there be in the co-operative operation no industry motivated by an apparent source of bright young lads for little money rather than by a long time objective honestly promoting an education plan. On the other hand, mere assurance of the sound policy intent of the company administration is not enough; adequate controls must be provided to insure that the policy carries through to the immediate environment of the student. This is one of the top hazards of the co-operative plan and cannot be overemphasized in importance.

SCHEDULE

The schedule on which a co-operative operates is influenced by a number of factors, especially the following:

(*a*). Whether the school is all-co-operative.
If not 100 per cent co-operative, the schedule of the non-co-operative operation usually governs the period of co-operative alternation in the interest of simplicity and minimum cost.

(*b*). The distance between school and co-operating industries.
Location of the school close to a large industrial area generally is presumed essential to co-operative operation. By increasing the period to at least 12 weeks and avoiding "earn while you learn" recruiting, distances of several hundred miles are operating successfully.

(*c*). The seasonal schedule of industries personnel need and supply.
Industry generally prefers a reasonably constant supply of co-operatives throughout the year. It usually is wise to avoid initial or larger assignments to industry during the summer. With the spring crop of new graduates on its hands and the disruption of many vacations, summer is the least favorable industrial period.

Unfavorable experience with accelerated schedules in non-co-operative curricula during the war, indicates that where a simple alternating co-operative schedule is not feasible, care to avoid an excessively long unbroken assignment on campus is advisable.

A unique co-operative schedule has been devised and operated at Massachusetts Institute of Technology with notable success for over a quarter century. It defers admission until the close of the second year of the regular curriculum. Applicants who, by their two year performance, have demonstrated superior qualifications are admitted by interview with the co-operating industrial personnel.

By this means a quality program is stressed and the 2-year preparation in the basic engineering courses facilitates assignment to more satisfactory technical activity in industry. Following admission to the program, a simple alternating schedule of four 4-month industrial periods ensues. This extends the student into graduate status for one year, terminating with the master's degree. Ten curriculum periods are covered during five years by providing nine terms at Massachusetts Institute of Technology and an equivalent of one term in the form of evening classes during the four industrial periods.

Among the more recent entrants in the co-operative field, Rensselaer Polytechnic Institute and Cornell University have devised variations of the Massachusetts Institute of Technology design which are of interest. Both of these provide for a co-operative schedule in parallel with a non-co-operative schedule and for the screening of students from the regular group for admission to the co-operative.

Rensselaer Polytechnic Institute screens late in the first year, splits the co-operative recruits into two substantially equal groups which are alternated with each other between school and industry for three periods in industry. The alternation is interrupted in the fourth year to permit all being on campus as candidates for the bachelor's degree. A fourth period in industry is scheduled in the fifth year and the program is completed with the master's degree after 14 calender periods of which ten are terms scheduled at Rensselaer Polytechnic Institute.

The Cornell program is confined to mechanical and electrical students. As at Massachusetts Institute of Technology, screening and admission occurs in the fourth term (or semester) late in the second year of the regular program. All engineering curricula at Cornell require five years or ten terms for the bachelor's degree. Not wishing either to extend the co-operative beyond the 5-year regular program or to schedule curriculum classes during industrial periods, there are available in industry three periods, each of four months. This total of one calendar year in industry, although somewhat less than provided in most co-operative programs, is believed adequate and preferable to alternative possibilities for Cornell.

The circumstance of three operating periods per calendar year, coupled with a program of three periods in industry, makes possible a schedule of utmost simplicity, and one notably suited to the requirements of the small-sized selective-type co-operative. To describe this schedule, let the three successive industrial periods be designated *A*, *B*, and *C*. The co-operative students recruited during the fourth term all remain on campus during the summer for their fifth curriculum term. These all go to industry in the fall and then simply alternate as one unit between industry and campus until the three industrial periods are completed.

Now let the calendar periods be designated fall, spring, and summer. The three industrial periods then will occur as follows: *A* in the fall, *B* in the summer, and *C* in the spring. When in full operation the plan provides for a constant number always in industry yet does so without

ever splitting any recruited unit into the conventional halves. Let us call it "unitized" operation.

This avoidance of split groups obviously simplifies operation (and eliminates the little annoying question as to which of the split groups has the better schedule; whether to be on campus for football, or to defer industry until better prepared by the fifth term of study.) But it has one really important advantage for the small-sized co-operative, as follows. Let the number recruited in one curriculum be limited to 20 students. This is a reasonable and economic size for one classroom section, but splitting would provide only ten in a class and would double the number of classes or courses to be operated. In fall and spring most co-operative classes need not be separated from those for regular students, but summer poses a serious economic problem. Whereas a split operation in summer requires half-size classes in curriculum terms 5, 6, 7, 8, unitized operation requires only curriculum terms 5 and 8 with full-size classes. Furthermore the Cornell plan permits all curriculum terms for co-operatives in the fall and spring to synchronize with those of the regular curriculum schedule, an important feature where most courses are not offered both in fall and spring terms.

There is one possible disadvantage to the unitized schedule: the job gradation in the rising sequence fall, summer, spring must be seasonal. In the larger industries, however, this is no real problem, and compared with the disadvantage of initial assignment to industry in summer, which characterizes split operation, seasonal gradation seems preferable.

NEW HORIZONS

The engineering co-operative of Herman Schneider continues to develop as a major element in engineering education. No longer is it limited to local area operation; no longer is it feasible only in an all-co-operative school; no longer is it on trial either by school or industry. This article has discussed recent developments in operation which expedite new variations of the plan in respect to schedule and size of enrollment. Expanding interest continues to provide new work areas for the co-operative plan.

Notable among the afore-mentioned areas is the United States Government. At the annual meeting of the ASEE last June[3] it was reported that satisfaction is being experienced with a co-operative program between the University of Cincinnati and the Army Air Forces, Air Material Command, at Wright Field, Dayton, Ohio. This operation involves Civil Service procedure and is of particular interest by reason of the provisions worked out to make the program feasible under Civil Service. Government laboratories in the Washington area are indicating interest in the Civil Service co-operative development, and the possibilities of the idea invite some considerable thought regarding policy, trends, and opportunities.

There also must be adequate emphasis on the placement problem of the co-operative operation. Not only is it essential to recognize the individual interests and aptitudes of the student when arranging his industrial assignment; not only is it necessary to make available industrial assignments suited to the student; but requisite to these is adequate analysis of the educative function desired (*a*) of the job (*b*) for the student (*c*) in the curriculum.

Most engineering college students in the upper scholastic status, given the choice, will reach for a laboratory assignment in preference to assignment out in the factory areas of industry. Among other reasons for this, the most impelling perhaps is the influence of his campus experience; it constitutes his most available criterion of what is interesting and worthwhile in engineering.

But does this laboratory assignment offer educative features, other than technical, not equally available on campus? The chances are that it does, but it may not do so; and even if it does, might a factory assignment differentiate the more between school and industry in fulfilling the larger purpose of the co-operative? Whether in laboratory, factory, or office, I would urge that the educative value of any specific assignment opportunity can profit by more analysis than it is likely to get under the pressure standards currently existent no less on campus than in industry. It is not enough that the student be happy on the job. Is he just learning more science and technique as on campus or is he learning the organization, operations, human relations, and responsibilities which characterize the successful industry and which elude effective understanding in campus classroom or laboratory?

If he is doing the latter, he will understand why the engineering co-operative has so many staunch alumni.

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Metal-Atom Movement Tracers

Radioactivity currently is being used by scientists at the General Electric Company laboratories, Schenectady, N. Y., to trace the movement of atoms in metals.

It has been found that atoms within a block of silver may move between the grains as fast as one-tenth of an inch per week at 500 degrees centigrade, whereas atoms passing through the grains take about 10,000 years to move the same distance. The experiment was conducted with a radioactive isotope, made by the Oak Ridge Laboratories, Tenn., called "silver-110," which was electroplated on the surface of an ordinary silver block. After several hours at 500 degrees centigrade, the specimen was cooled and layers the thickness of tissue paper were shaved from the block. Each layer was checked with a Geiger counter, to determine how far into the block the tagged atoms had gone.

By learning in this manner how atoms behave under various conditions, scientists will be able to design metals for specific jobs.

An Electro-optical Shutter for Photography

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The advent of the "all-electric" shutter makes possible the detailed photographic study of light from very rapidly changing self-luminous objects. Shutter control is sufficiently positive and accurate to permit operation at any preselected instant with a precision of 5×10^{-9} second. This article presents the theory and describes the development of this simple, reliable, and compact optical shutter which utilizes a Kerr cell as a light valve.

THE INCREASED tempo of scientific activity during the last few years has resulted in a demand for optical investigations of very rapidly changing phenomena. Mechanical means have been employed to yield photographic exposure times down to about 50 microseconds, and special flash lamp and other techniques have resulted in photographic records with effective exposure times in the microsecond range. The electro-optical shutter provides a very versatile and practical means for obtaining exposure times over a very wide range. With the aid of such a shutter routine photographic studies of electric discharges have been made using an effective exposure time of 0.000,000,04 second.

The novel feature of an electro-optical or Kerr cell shutter is that there are no mechanical moving parts, the speed of operation depending only upon the rapidity with which a required voltage can be applied to the Kerr cell electrodes. These electrodes are immersed in a fluid which exhibits uniaxial birefringence when under the influence of an electric field.

The phenomenon of electric birefringence was discovered by J. Kerr in 1875.[1] One of the early applications of this effect was made in the construction of a light valve, now commonly called a Kerr cell shutter, for the measurement of very small time intervals.[2] The ordinary Kerr cell is composed of two flat plates or electrodes immersed in a fluid which becomes birefringent upon the application of an electric field. When such a cell is oriented between two polarizers crossed for minimum transmission the arrangement constitutes an optical shutter. With no voltage applied to the cell, light cannot be transmitted because of the crossed polarizers. A voltage applied to the electrodes has the effect of altering the state of polarization of the light, and transmission through the second polarizer is then accomplished.

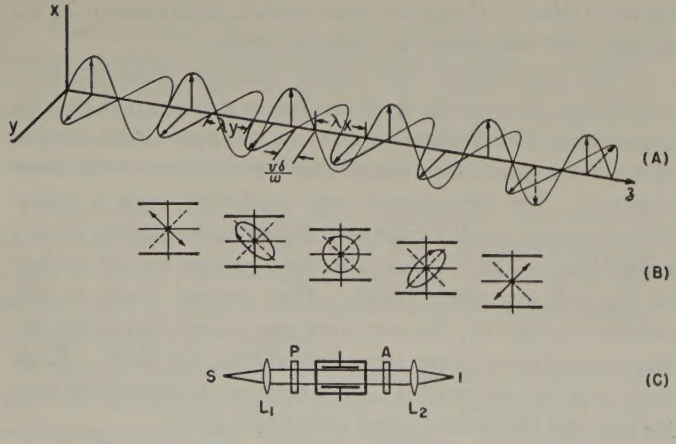

Figure 1. Principle of operation of a light valve

$\delta = 2\pi KlE^2$ = *the time phase-difference angle*
$v' = (v_x^{-1} - v_y^{-1})^{-1}$

The very small time lag between the application of voltage to the electrodes and the appearance of birefringence has led to the application of such shutters to

1. Measurement of the time lag in fluorescence.[3]
2. Study of early stages in spark discharges.[4]
3. Spectral studies of electric discharges.[5]
4. Measurement of the velocity of light.[6]
5. Modulation of light in telephotography.[7]

In the first three activities listed, an electro-optical shutter was connected across a spark gap by means of an adjustable length of transmission line. As the gap voltage was increased the shutter opened. The occurrence of a discharge caused the cell voltage to collapse suddenly at a time which depended upon the length of the transmission line between the gap and the Kerr cell electrodes. By this means, various stages during the spark discharge were examined. The last two programs listed utilized Kerr cells with varying voltages applied to their electrodes. There was however no intention of developing an optical shutter for use in a camera. In 1926, J. W. Beams[8] introduced the first full cycle (closed-open-closed) shutter using an arrangement of two Kerr cells. This very practical application has been slow in coming because successful optical shutters of large aperture require the accurate timing and control of high voltages. Interest in the photography of very high speed phenomena has increased steadily in recent years, and the development of the electric art has been so rapid, that simple techniques for generating and switching high-voltage pulses with great precision are standard practice.

The information presented in this article is the result of work done in one part of a proposed program of basic research on electric discharges. In order to make a complete

Full text of paper **49-24**, "An Electro-optical Shutter for Photographic Purposes," recommended by the AIEE instrument and measurements committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*.

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optical study of a phenomenon with a duration of a few microseconds, it was necessary to use a camera with a very accurately controllable shutter that would enable the attainment of exposure times of less than a microsecond. The electro-optical shutter was chosen as the only solution to this problem. By controlling the type, duration, and instant of application of the voltage pulse applied to the cell electrodes, the photographic records with effective exposure time of 0.000,000,04 second were obtained at preselected intervals during the life of the phenomena being studied.

THE ELECTRO-OPTICAL KERR EFFECT

If a beam of polarized light is passed through a medium which is optically anisotropic, the velocity with which the light travels in the material depends upon the direction of the electric vector in the incident light. This means the substance is birefringent, that is: the index of refraction depends upon the direction of propagation and the plane of polarization of the light traversing the medium. There are many known substances which are normally isotropic, but which exhibit the property of optical birefringence when subjected to an electrostatic field. This phenomenon is known as the electro-optical Kerr effect.[9]

In the simple case of a uniaxial birefringent material, there is one axis along which the index of refraction is not dependent upon the direction of the electric vector in the incident light. This axis is termed the optic axis of the material.[10] Substances which exhibit the electro-optical Kerr effect become uniaxially birefringent under the influence of an electric field, the optic axis being in the direction of the field.

According to the present state of the theory, the electro-optical Kerr effect is related intimately to molecular structure. It has been found that for a liquid or gas to exhibit a Kerr effect, it is essential that the individual molecules possess an aeolotropic optical polarizability with respect to a set of axes in the molecule. In addition, however, the molecules must have either a permanent dipole moment or must be anisotropically polarizable by the application of an electric field, or both. It is not surprising therefore that the materials with the largest Kerr constants also have high dielectric constants.[11,12]

The statistically random orientation of molecules for liquids and gases in the normal state results in a condition of optical isotropy. In general, the application of an electric field produces a polarization assymmetry and also a tendency for the molecules to prefer a definite orientation, mainly, because of the permanent dipole moment. The orienting effect, although opposed by the thermal molecular motion, results in a more or less statistically average regular arrangement of molecules under the influence of the applied electric field. Under these conditions the substance exhibits an over-all molecular assymmetry and, generally, optical anisotropy. Orientation of the molecules is not a necessity, however, as the induced electrical polarization alone also will cause optical anisotropy, but for substances with high Kerr constants, molecular orientation accounts for the largest part of the Kerr effect.[13]

The rapidity with which the molecules of a substance

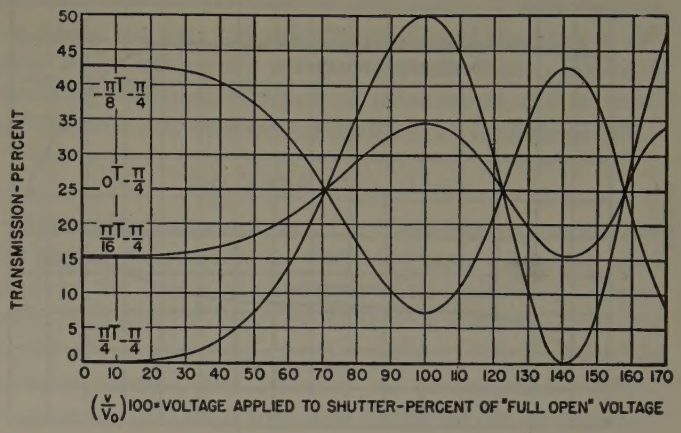

Figure 2. Electro-optical characteristics of a Kerr cell shutter

$$_{\varphi}T_{\alpha}=50\left\{\cos^2(\varphi-\alpha)-\sin 2\varphi \sin 2\alpha \sin^2\left[\frac{\pi}{2}\left(\frac{v}{V_0}\right)^2\right]\right\}$$

= the percentage optical transmission when the polarizer and analyzer angles are φ and α respectively

$$_{\pi/4}T_{-\pi/4}=50 \sin^2\left[\frac{\pi}{2}\left(\frac{v}{V_0}\right)^2\right]$$ *= the transmission at any applied potential, v*

assume a statistically average preferred direction of orientation is related to the chemical structure, viscosity, and other factors, and can be determined approximately using certain simplifying assumptions by introducing the concept of relaxation time. The relaxation time for the Kerr effect is an average molecular time constant, which may be considered as a measure of the effective time required for a substance to return to its optically isotropic state after the electric field has been removed. For many substances this time is of the order of 10^{-9} second.[14]

DESCRIPTION OF THE KERR EFFECT

For a clearer picture of the influence of an electric field upon a liquid which exhibits the Kerr effect, consider the arrangement of apparatus shown in Figure 1*C*. A beam of light, plane polarized at an angle φ with respect to the applied electric field enters the cell. The electric vector in the incident light may be resolved into two components, one parallel and the other perpendicular to the applied field. These components traverse the cell fluid with different velocities, v_x and v_y, and as a result possess different wave lengths as shown (much exaggerated) in Figure 1*A*. As a

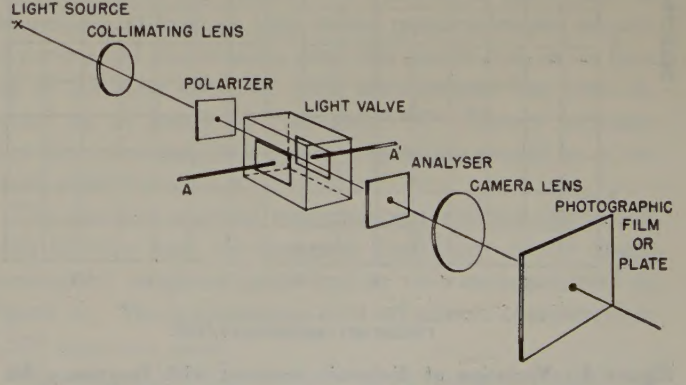

Figure 3. Components of a Kerr cell camera

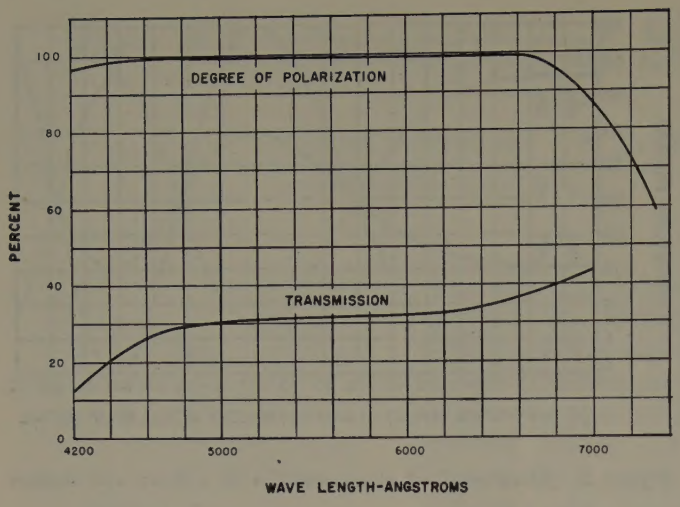

Figure 4. Characteristics of J film polaroid

consequence, if the applied electric field is kept fixed, the two components will differ more and more in space phase as they proceed through the liquid. This is the equivalent of stating that there will be a continuously increasing difference in time phase between the two components of light as they traverse the cell. Since the state of polarization of the light at any point is dependent upon the difference in time phase between the two components, the resultant light emerging from the cell, in general, no longer will be plane polarized. See Figure 1*B*. If the angle φ of the plane of polarization upon entering is 45 degrees, and the angular time phase difference between the components, δ, is an odd multiple of $\pi/2$, the light will become circularly polarized. If δ is an odd multiple of π the emergent light will be plane polarized at 90 degrees to the plane of polarization of the entering light. For δ equal to an even multiple of π the light leaves polarized as it entered. For all other values of δ the light will be elliptically polarized.

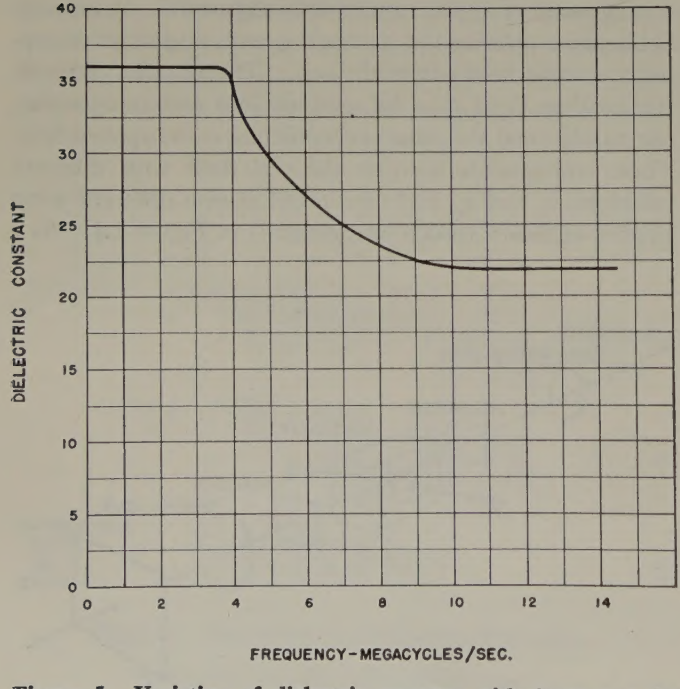

Figure 5. Variation of dielectric constant with frequency for nitrobenzene

One of the factors which determines the angular time phase δ is the Kerr constant of the fluid. The Kerr constant is defined by the equation:

$$\frac{n_x - n_y}{\lambda} = KE^2 \qquad (1)$$

where $\mathcal{N}_x$ is the refractive index in a direction parallel to the electric field, $\mathcal{N}_y$ is the refractive index in a direction perpendicular to the electric field, λ is the wave length in a vacuum of incident light in centimeters, and E the applied electric field in electrostatic units. Time phase angle is given by

$$\delta = 2\pi lKE^2 \qquad (2)$$

where l is the length of the light path under influence of the electric field in centimeters, E is the applied electric field in electrostatic units, and K is the Kerr constant for the substance in (cgs) electrostatic units.

The approximate Kerr constants, dielectric constants, and resistivities for substances in electro-optical work are

Substance	Kerr Constant	Resistivity (Ohms-Centimeter)	Dielectric Constant
Carbon disulphide CS_2	3.6×10^{-7}	10^{16}	2.5
Chloroform $CHCl_3$	-3.2×10^{-7}	10^{8}	5.0
Acetone C_3H_6O	16×10^{-7}	10^{7}	20.0
Nitrobenzene $C_6H_5NO_2$	400×10^{-7}	10^{10}	36.0

The Kerr constant for most substances depends not only upon temperature, but is a function of the wave length of the incident light as well. However, this is not too serious a difficulty even when careful quantitative work is to be done. It is a simple matter to keep the cell at constant temperature, and optical corrections for dispersion in the Kerr effect can be provided easily. These corrections were not required in the work described in the following.

ELECTRO-OPTICAL CHARACTERISTICS OF A KERR CELL SHUTTER[15]

The percentage optical transmission of a Kerr cell shutter as a function of the applied electrical field, may be obtained with the aid of equations 1 and 2 as

$$\varphi T\alpha = 50[\cos^2(\varphi-\alpha) - \sin 2\varphi \sin 2\alpha \sin^2 \delta/2] \text{ per cent} \qquad (3)$$

where φ is the angle between the plane of polarizations of the entering light and the applied electric field, α is the angle at which the analyzer is set relative to the applied electric field, $\delta = 2\pi lKE^2$ is the angular time phase difference between the emerging components of light parallel and perpendicular to the applied electric field, and $\varphi T\alpha$ is the percentage optical transmission when the polarizer and analyzer angles are φ and α respectively.

For optimum operation as a shutter, $\varphi = 45$ degrees and $\alpha = -45$ degrees and the transmission becomes

$$_{\pi/4}T_{-\pi/4} = 50[\sin^2 \delta/2] \text{ per cent}$$

$$_{\pi/4}T_{-\pi/4} = 50[\sin^2 (\pi lKE^2)] \text{ per cent} \qquad (4)$$

If the electric field required for full open operation is taken

to be E_0 corresponding to an applied potential difference V_0, the transmission as a function of the potential difference, v, applied to the cell may be written

$$\pi/4T_{-\pi/4}=50\left[\sin^2 \pi/2\left(\frac{v}{V_0}\right)^2\right] \text{ per cent} \qquad (5)$$

Figure 2 shows the variation of transmission of an electro-optical shutter as a function of applied potential for several angular orientations of the plane of polarization of the entering light. The analyzer is fixed at $\alpha=-45$ degrees. These curves were plotted using equation 3 which ignores the attenuation of light by the various components of the Kerr cell and does not take into account dispersion in the Kerr effect. The amount of light passed by the shutter increases with the applied potential until the light becomes polarized in the plane of transmission of the analyzer, *A*, in Figure 1*C*. At this voltage, the shutter is full open, but the transmission is 50 per cent because half of the light is rejected by the polarizer, *P*. Further increase in voltage causes a decrease in the light transmitted as shown.

From equation 3 and Figure 2 we observe two important conditions for the successful operation of the electro-optical shutter:

1. If there is to be zero transmission when no voltage is applied to the Kerr cell, the polarizer and analyzer must be crossed accurately, that is $(\varphi-\alpha)=90$ degrees.

2. The optimum condition of operation is obtained when $\varphi=45$ degrees.

The first condition is the more critical one, inasmuch as it affects the completeness of closure of the electro-optical shutter. Fortunately the critical alignment of polaroids is a simple matter if a photo-sensitive detector is used to obtain the null position. The second condition, namely $\varphi=45$ degrees is not critical. Accuracy within a few degrees of 45 degrees can be tolerated. Equation 3 was obtained for operation of the Kerr cell under certain simplified conditions. Because of the attenuation of light by the fluid the polarizer and the analyzer, and because of dispersion in the Kerr effect, neither full nor zero transmission actually is attained with increasing voltage applied to the cell.

COMPONENTS OF A KERR CELL CAMERA

The components required to make a Kerr cell camera are shown in Figure 3. Light from the source to be photographed is gathered and rendered parallel by the collimating lens. The polarizer and analyzer are set accurately at an angle of 45 degrees to the electric field and at 90 degrees to one another. For the camera lens and film combination we employed an *f:4.5* Speed Graphic using 4 by 5 inch film or plate.

Several different polarizing agencies were tried. Nicol prisms, although having an excellent transmission characteristic, are bulky, expensive, and introduce a limited width of field. Polaroid glass is inexpensive, but zero transmission of a crossed pair was difficult to obtain—even with selected pairs. In addition, there were also mounting problems. Best over-all results were obtained with polaroid *J* film sheet. This film comes in 12 by 12 inch sheets, it is inexpensive, and experience has shown that suitable uniform sections can be found in any sheet. These sections are easily cut out, properly oriented, and fastened to the glass cell windows by means of scotch tape. Figure 4 shows the variation of degree of polarization and percentage transmission with wave length for *J* film polaroid.[16]

THE KERR CELL FLUID

Among the fluids, nitrobenzene ($C_6H_5NO_2$) seems to have the highest Kerr constant. For this reason, it has long been used as the active substance in Kerr cell work. Commercially known as oil of mirbane, it is a straw yellow oily liquid with a strong odor of shoe polish. It is very soluble in ether, alcohol, and benzene, but not in water. Nitrobenzene vapor is quite toxic and the liquid can be absorbed by the body through the skin, causing blood poisoning. Care in handling is consequently essential.

The dielectric constant of nitrobenzene at 20 degrees centigrade is 36. The variation of dielectric constant of nitrobenzene with frequency is given in Figure 5.[17] As shown, the dielectric constant decreases from 36 at three megacycles per second to 22 at ten megacycles per second and continues at the latter value up to 13 megacycles per second. Further data are not available. This would seem to indicate the existence of a first order Kerr effect at frequencies at least as high as ten megacycles per second. Experimental observations bear this matter out, as no time lag in the Kerr effect for pure nitrobenzene has been detected up to nearly 10^{-9} second.[18,19,20] Theory indicates that the relaxation time due to orientation should be of the order of 10^{-9} second.[21]

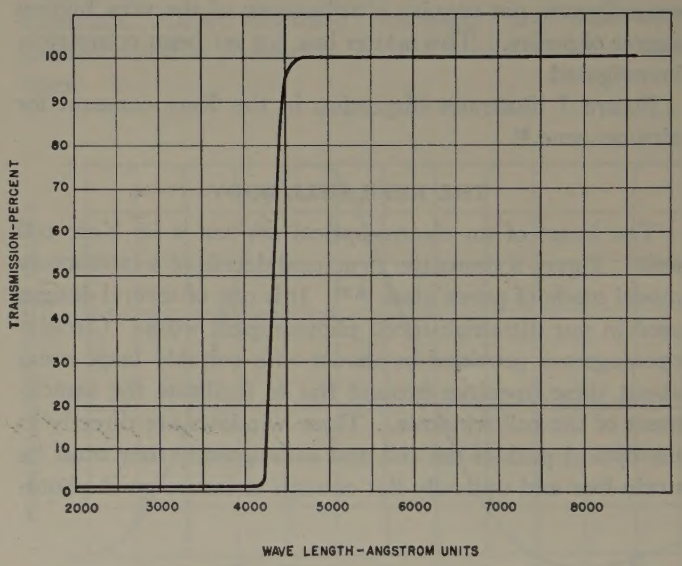

Figure 6. Spectral transmission of nitrobenzene sample of one centimeter thickness

The absolute spectral transmission for a one centimeter path in very pure nitrobenzene (resistivity $\sim 10^{10}$ ohms-centimeter) is given according to our measurements in Figure 6. The transmission cuts off almost completely at 4,200 angstrom units.

There are other facts concerning nitrobenzene which are

of interest. The refractive index is approximately 1.553. The dielectric strength of commercial oil of mirbane is about 45,000 volts per centimeter and its resistivity is of the order of 10^6 ohms-centimeter. When the liquid is purified, the dielectric strength may be increased to 150,000 volts per centimeter and its resistivity brought up to 10^{10} ohms-centimeter.[22] Under conditions of pulsed voltage, nitrobenzene undoubtedly will withstand much higher electrical stresses although no data have been found for such conditions. However, it has been reported that carbon disulfide will withstand a gradient of 10^6 volts per centimeter for periods of the order of 10^{-7} second.

The Kerr constant for nitrobenzene as determined by electrostatic methods has been shown to be directly related to its purity as indicated by its resistivity. For this reason elaborate precautions usually are made to obtain the highest possible purity and resistivity. Because nitrobenzene is a powerful solvent, great care is exercised in the cleansing and handling operations encountered in the construction of Kerr cells.[23] It should be noted here that the operation of a Kerr cell with voltage pulses of very brief duration (10^{-7} second) may not require nitrobenzene of the very highest degree of purity. This matter has not yet been completely investigated.

Figure 7 illustrates dispersion in the Kerr constant for nitrobenzene.[24]

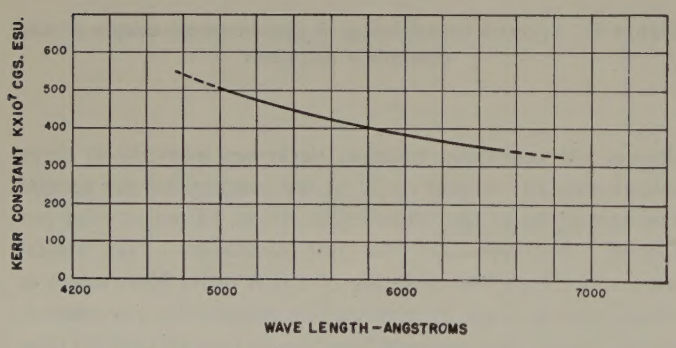

Figure 7. Dispersion in the Kerr constant for nitrobenzene

THE KERR CELL BODY

The heart of an electro-optical shutter is its Kerr cell unit. Figure 8 shows the structural details of a satisfactory model made of pyrex glass.[18,23] It is one of several designs used in our ultrahigh-speed photographic work. Circular openings are provided as shown with suitably large areas about these openings ground flat to facilitate the attachment of the cell windows. These windows are directly in the optical path of the cell and consequently they must be strain-free and optically flat enough to insure good photographic definition in the images formed by the associated lens system. Since polarized light is used with the cell, it is obvious that if the windows are not strain-free they will produce alteration of the state of polarization and poor operation of the light valve will result. The degree of optical flatness of the cell windows depends upon the use for which the camera is intended. Because the refractive index of nitrobenzene is much closer to that of glass than air, the tolerance on flatness for the inside surfaces of the windows can be as much as ten times greater than that for the outside surfaces.

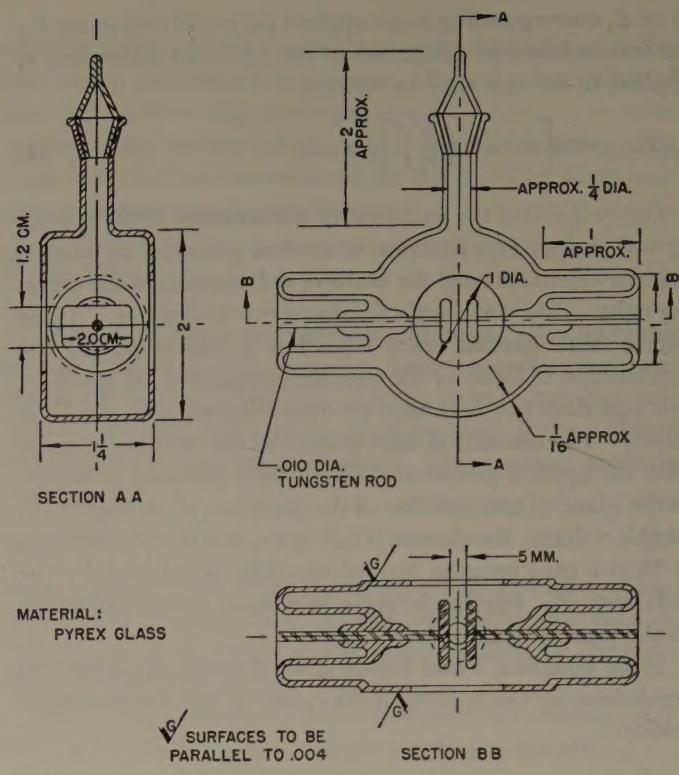

Figure 8. Kerr cell body

The cell windows are usually completely masked excepting for a small opening for the passage of light. This serves two purposes: reflected light from the electrode faces is prevented from causing extraneous photographic images, the useful light beam area is limited to a region of comparatively uniform electric field in the cell.

In the earlier models the glass windows were attached to the cell body with ceresin wax as a cement. Later, experimental cell models with fused windows were satisfactorily constructed, but these have not yet been used. The electrode plates were made of pure nickel silver soldered to tungsten stems which in turn were sealed into the pyrex body. The plates were rounded at the edges in order to minimize electrical stresses and the consequent possibility of breakdown.

DESIGN CONSIDERATIONS

The design of a Kerr cell shutter depends upon many factors which involve both electrical and optical considerations. After some thought has been given to the nature of the photographic problem in a given instance, the question of desirable shutter aperture must be settled. A good design will have to be a compromise between certain physical and electrical factors, since the possible aperture is dependent upon the width and spacing of the cell electrodes and these dimensions in turn are affected by the length of the electrodes and the availability of electrical means for obtaining and switching voltage to the electrodes. As an example

consider equation 4. The condition for full open operation of a shutter is

$$\pi l K E_0^2 = \pi/2 \qquad (6)$$

Taking $E_0 = V_0/d$ where d is the separation of the plates, this leads to

$$V_0 = 300 d \sqrt{\frac{1}{2lK}} \text{ volts} \qquad (7)$$

Since the Kerr constant, K, at best is of the order of 10^{-5}, shutters of wide aperture will require very high voltages. The alternative of increasing the length of the plates adversely affects the angular field and limits the rapidity with which the shutter can be operated by increasing the electrostatic capacity of the cell. The Kerr cell shown in Figure 8 is full open with approximately 12,000 volts applied to the cell electrodes. Reference to Figure 2 will show that the most effective utilization of equipment will be obtained if applied voltage is 80 to 90 per cent of the full open voltage.

VOLTAGE FORMING SYSTEM FOR A KERR CELL SHUTTER

Up to this point, we have discussed the Kerr cell shutter alone and given little attention to the electrical requirements which are necessary to its successful operation. To convert the device described to a useful instrument, it is necessary to be able to apply voltage pulses of suitable magnitude and duration to the Kerr cell at accurately predetermined instants. The general problem is too broad to be discussed here. It is sufficient to remark that a large variety of techniques are applicable, and that many elaborate control methods similar to those recently developed for radar may be adapted to this specific use. From the abundance of methods utilizing these techniques, one may choose those systems which best meet specific requirements of accuracy, stability, and simplicity. Since versatility in operation is a characteristic of most electronic control means it will be found that a wide range of applications will be served by a single apparatus. For example, adjustments of the duration and magnitude of the voltage applied to the cell electrodes can be utilized to vary the effective exposure time over a wide range, and control of the instant of operation of the shutter allows selective photographic studies to be made.

The voltage forming system which was selected for use in obtaining photographic records of the various stages during the sudden electrical vaporization of fine wires provided an effective exposure time of 0.000,000,04 second when used with the Kerr cell shown in Figure 8. In operation, an accurately controlled initiating signal determines the instant at which the voltage pulse shown in Figure 9*A* is applied to the Kerr cell electrodes. This pulse reaches a magnitude of 8 kv and has a duration of 0.18 microsecond. The transmission of the shutter as a function of time, as shown in Figure 9*B*, is obtained with the aid of Figure 2 or equation 5. Assuming 64 per cent as an average transmission for each polarizer, the over-all transmission of the shutter, including absorption by the polarizers, can be obtained by multiplying the ordinates of Figure 9*B* by 0.41. Seventy per cent of the area under the transmission versus time curve lies between 0.07 microsecond and 0.11 microsecond. The effective exposure time of the shutter is given therefore as 0.04 microsecond. This value has been checked approximately with the aid of a photosensitive detector.

For special problems, where photographic records of very brief exposure time are required, the accuracy with which the instant of maximum transmission for the shutter can be preselected may become an important matter. In general the midpoint in the exposure time will be determined by the electric control of the voltage forming system. Using standard pulsing techniques it was found that the initiation of operation of the shutter could be controlled to better than 0.005 microsecond.

PHOTOGRAPHIC RESULTS

The Kerr cell camera described was used successfully to make complete optical studies during the sudden vaporization of various types of fine wires. These wires were supported in a horizontal position by clamping the ends between phosphor bronze contactors. Vaporization was accomplished electrically by the controlled discharge of a capacitor. Other electrical discharges have also been studied and it is planned to present results of these tests later.

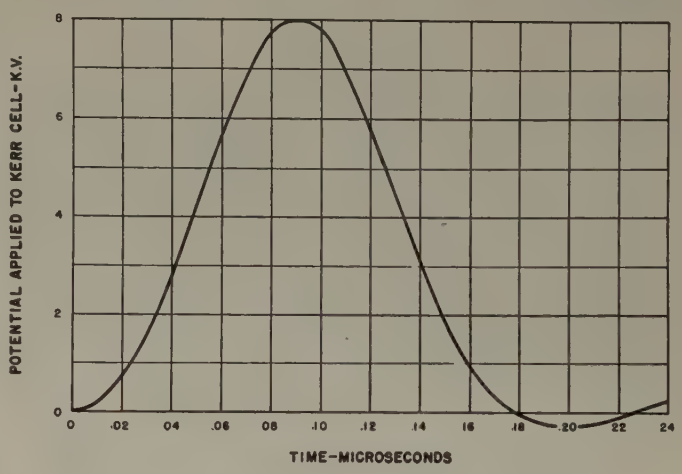

Figure 9*A*. Voltage applied to Kerr cell terminals

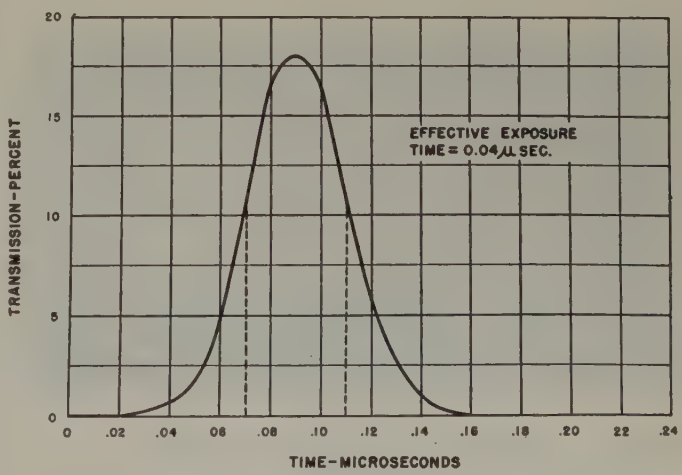

Figure 9*B*. Kerr cell transmission for voltage pulse of Figure 9*A* showing effective exposure time of 0.000,000,04 second

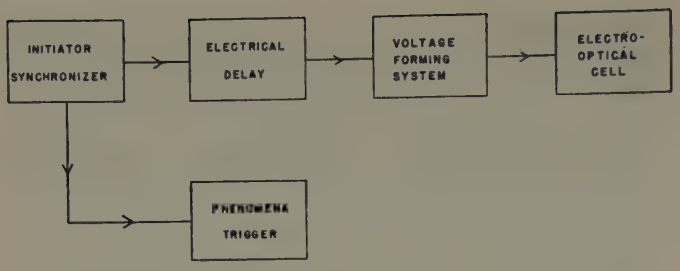

Figure 10. Block diagram of Kerr cell camera system

The sequence of operations employed in our optical studies is shown in the block diagram of Figure 10. A passive network was used to obtain adjustable delay. By changing the amount of electrical delay, whole series of photographic records for various types of electric discharges were obtained at intervals as small as 0.025 microsecond after the discharge voltage was applied to the electrodes. One photograph was obtained during each discharge. Figure 11 is a photograph taken at 0.60 microsecond after the application of voltage to a short length of tungsten wire. The effective exposure time was 0.04 microsecond. Quite clearly the techniques which were employed are applicable, without much change, to other problems.

CONCLUSIONS

The electro-optical shutter appears to be an excellent instrument for obtaining controlled exposure times of less than 100 microseconds, and for photographic studies which require exposure times of less than one microsecond the Kerr cell is almost the only practical solution. Since the inherent time lag in the electrical birefringence of nitrobenzene is of the order of 10^{-9} second, the attainable rapidity of shuttering is limited by the availability of suitable techniques for fast switching of voltage. The ease with which the operation of an "all-electric" shutter can be synchronized with any phase of phenomena under study gives them an outstanding advantage over other types.

As an extremely fast photographic shutter, the Kerr cell will be an invaluable research tool in many fields. Among the high-speed self-luminous subjects which it is hoped to study with this device are: many types of electric discharges, the history of arc formation, cathode spot phenomena, the action of fuses, and so on. The instrument will find applications also in the study of certain basic problems in mercury arc rectification, combustion problems, detonation phenomena, and ballistics. When non-self-luminous objects are to be photographed, the use of a Kerr cell shutter in conjunction with a synchronous flash lamp makes possible far shorter exposure times than are attainable at present with flash photographic equipment. In addition to these applications, an entire field of "gated optics" analogous optically to radar is opened by use of the electro-optical shutter as a light modulator.

The use of a multiplicity of electro-optical shutters operated in rapid sequence offers a method of obtaining framing rates of many millions per second.

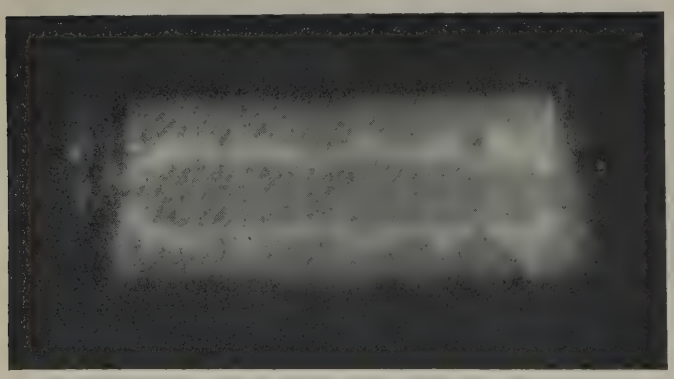

Figure 11. Photograph obtained during vaporization of a fine tungsten wire

Taken at 0.60 microsecond after initiation of the electrical discharge. Effective exposure time is 0.000,000,04 second

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Transformer Impulse Failure Detection Methods

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COMMERCIAL impulse tests, which have been performed for approximately 16 years, are conducted in various manners depending upon the rules in effect at the time. Periodically, the rules are amended to incorporate improvements in the technique of testing. It is a purpose of this article to show how excitation during an impulse test complicates the test and interpretation of results.

Almost everything has been done, consistent with the proved ability of the equipment, to simplify the test program. A certain period of proving is necessary before standards are amended, yet it is difficult to gain experience with a new technique until it is permitted by the standards. However, the American Standards Association's Standard, C-57, "American Standards for Transformers, Regulators, and Reactors," has been newly amended to allow recently developed techniques.

The record shows that power current does not follow the impulse failure path except under special circumstances. Furthermore, the complications of the test necessitate conditions that confuse the interpretation of results. If a failure is suspected while testing with excitation, it is axiomatic to eliminate excitation as well as the exciting equipment from the circuit and concentrate on the winding under test. This permits the elimination of protective devices from windings not being tested, as well as isolating gaps in the impulse generator circuit. When protective devices are used, it is very easy to confuse the operation of the device with a failure in the equipment, especially if the failure involves a relatively small section.

After some eight years of impulse testing with excitation, and finding that excitation only added complications to the test, some testing was carried on without excitation.

Fewer lightning arresters or other protective devices were used on windings other than the one being tested. This did not eliminate the disturbances produced by the protective devices, but it did reduce their number and simplified the preliminaries to a test which further reduced the complications that arise when a failure is suspected.

It is undesirable to stress any winding not being tested. It is reasonable to consider methods which will so protect these windings and at the same time not produce the disturbances associated with some protective devices.

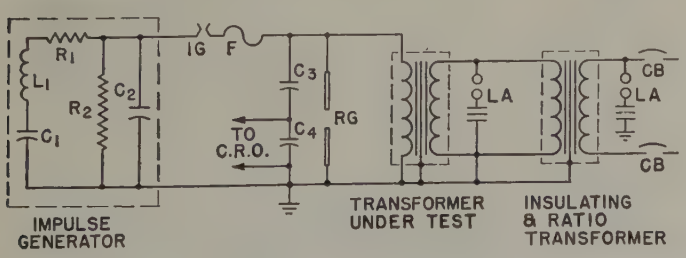

Figure 1. Simplified impulse generator discharge circuit with normal frequency excitation

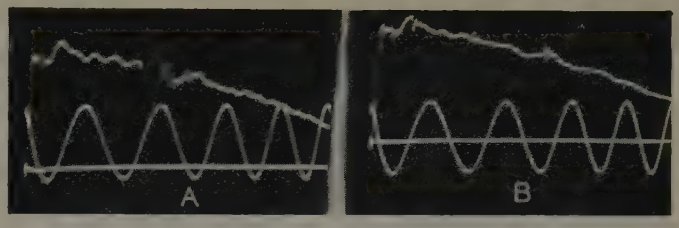

Figure 2. Full waves applied to a high-voltage winding

A—Low-voltage bushing flashover caused disturbance at about 19 microseconds
B—Full wave after three lightning arresters were applied to the excitation circuit

Upon eliminating excitation, practical use can be made of linear resistors as protective devices. In fact, in many instances the winding not being tested can be short-circuited and grounded.

Since the cathode-ray oscillograph has proved a very dependable device, it is not surprising that additional uses have been suggested for failure detection. A method of measuring the current at the grounded terminal of the winding under test has been suggested as a means of failure detection. The procedure is to insert a shunt between the terminal and ground and apply the voltage developed across the shunt to the plates of the oscillograph. A recording would be made at reduced full-wave level and at full-wave level. Usually these neutral current oscillograms will consist of many frequencies and a mismatch is indicative of a change in the transformer's impedance, such as when a failure occurs. Small changes in impedance result in larger changes in the neutral current oscillograms than occur in the voltage oscillograms taken at the surged terminal.

Whether the current neutral method of measurement will detect all failures in a winding obviously depends considerably upon the characteristics of the transformer. Turn-to-turn failures involving no more than one-tenth of one per cent of the winding have been detected.

The quantity of evidence that another and less desirable side of the story exists is not great. It should be pointed out though that a record exists of a failure that was not detected by the neutral current method. It is believed that this experience is further verification that the steep-wave voltage levels are not perfectly co-ordinated with the $1^1/_2 \times 40$ levels.

A simplified diagram illustrating the impulse generator circuit connected to a transformer, which is to be excited during tests, is shown in Figure 1. Two oscillograms obtained during the test are shown in Figure 2.

Digest of paper **48-291**, "Experience with Transformer Impulse Failure Detection Methods," recommended by the AIEE transformer committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Mercury Arc Converter for Induction Heating

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SEVERAL INSTALLATIONS of 300-kw mercury arc frequency-changing equipment have been made in the United States for induction melting and heating applications. An analysis is presented of the basic circuit for electronic conversion of 3-phase power of commercial system frequencies into single-phase power of a frequency of the order of 1,000 cycles.

The performance of this type of electronic power-converting equipment is based upon simultaneous rectifier operation at the input frequency and inverter operation at the output frequency. A single mercury arc converter is used having three pairs of anodes connected to a single-phase high-frequency inverter transformer and a 3-phase rectifier transformer, as shown in the circuit diagram of Figure 1. The inverter operates into a tuned circuit consisting of the inductance of the heating coil and the capacitance of the bank of power-factor correction capacitors in parallel with the coil. Commutation of arc current is initiated by means

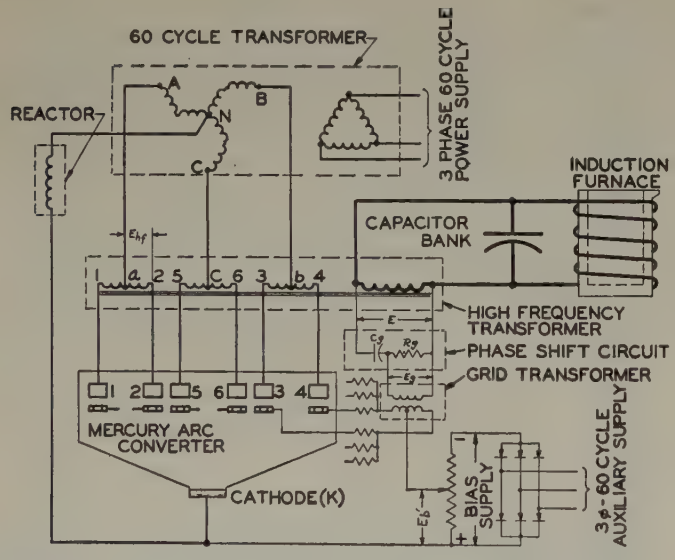

Figure 1. Circuit diagram of mercury arc converter for induction heating

of phase-controlled grids receiving potentials fed back from the high-frequency output circuit.

The mathematical analysis of self-excited rectifier-inverter frequency conversion operation under steady-state conditions includes the effect of commutating reactances and resistance losses in the transformer elements upon the voltage regulation. An equation can be derived for the high-frequency output voltage in terms of the equivalent d-c voltage, cathode current, commutating reactances, and resistance of the transformer elements, and the cosine of the firing angle. The usual analysis of the self-excited inverter in steady-state operation neglects the damping of the free oscillations between commutation periods. The steady-state operation is analyzed as a repeated transient, and the effect of damping on the output voltage regulation is taken into account.

Voltage control is available within a limited range by adjusting the angle of phase advance in the high-frequency feedback grid circuit. The problem of phase-angle shifting due to frequency variations can be analyzed, and the basic design of a compensating circuit can be described by means of a circle diagram. A wider range of voltage control also can be provided by means of taps on the high-frequency transformer output winding, or by means of phase control at the input frequency.

Electronic frequency conversion with mercury arc equipment, as compared to conversion with motor-generator equipment, is distinguished by the fact that the output frequency is determined by the resonant characteristics of the load circuit and control settings rather than by the fixed speed of rotation. The frequency adjusts itself automatically to changes in the load circuit as heating of the charge progresses. Because of this inherent tuning characteristic of the circuit, switching of capacitors during operation is unnecessary.

Ordinarily, in melting service, only one induction furnace is operated from mercury arc frequency-conversion equipment, but when it is required to operate two or more furnaces in parallel, this type of frequency changer possesses inherent advantages that are analyzed mathematically in comparison to fixed-frequency equipment. The principal advantages are that less output voltage change is necessary to prevent overloading of the conversion equipment and that frequency change due to paralleling furnace coils across the capacitor bank has less influence on the operation of the equipment.

Practical control circuits have been developed to apply this type of electronic frequency-conversion equipment to forging and foundry service. The operating efficiency is high and has the desirable characteristic of remaining relatively constant from nearly one-quarter load to full load. Installations of mercury arc frequency-conversion equipment have been made principally for the induction melting of high-alloy steels and some types of high-grade nonferrous alloys.

Installations of mercury arc frequency-changing equipment can be designed for connection to any available power line voltage. The inherent self-tuning characteristic results in simple operation with little attention required from the furnace operator.

Digest of paper 48-287, "Mercury Arc Frequency Converter for Induction Heating of Metals," recommended by the AIEE electric heating and electronic power converter committees and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Input Power Requirements of Television Receivers

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ASSOCIATE AIEE

A number of electric power utilities have been concerned somewhat over the television power load, which will represent an approximate load of two million kw for the ten million television receivers estimated to be in use in the next five years. This article covers the nature of the load represented by television receivers and the probable trend of television power requirements in the future.

ONE EFFECT of the recent war was to increase considerably the demand for electric power; while at the same time, curtailing normal expansion of electric generating equipment. For this reason, the electric power line load, represented by the rapidly increasing quantities of home television receivers, has elicited mixed reactions from the electrical utilities. In many instances, the anticipated increase in revenue may have been offset by the concern in the minds of electric power officials over an increased load which might be too much for their all-too-marginal reserve capacity. This factor plus the concern over undesirable low power factor loads have resulted in one or two instances in extra penalty charges levied upon television set users by the power companies.

This article covers briefly the nature of the electric power load represented by television receivers and projects the probable trend of television power requirements as the art progresses.

Except for actual magnitude, which will be discussed later, the most important characteristic of a power line load is its power factor. In this respect, television receivers are almost ideal. The television receiver like the radio receiver utilizes a-c power for heating the vacuum tube filaments and rectified power for operation of vacuum tube and associated circuits. The filament load is pure resistance and therefore is unity power factor while the rectifier power, although consisting in most cases of a nonlinear resistance load, is also very close to unity power factor. The actual nature of current flow in the rectifier tube depends mainly upon two factors: first, the size of the first filter capacitor, and secondly, the value of effective series impedance between the power line and the first filter capacitor, including the rectifier tube resistance. The most nonlinear current conditions occur when the first filter is large and the series impedance is small. This relationship is shown in Figure 1. In this case, current flow is concentrated at the peak of the voltage wave but is still fairly symmetrical with respect to the Y axis of the voltage wave and, consequently, represents a good power factor. In smaller television receivers in which rectifier and filament circuits are directly connected to the power line, the sum of these loads is the power line load of the receiver. Nearly all television receivers, however, except some of the very smallest ones, contain power transformers with secondary windings for plate and filament supply; and in these cases, the leakage reactance and charging current of the power transformer represents a reactive load. Efficiency of this type of transformer is, however, reasonably good and the power factor of the complete television receiver load has been better than 90 per cent in all cases which have been checked.

Another characteristic of television receivers which has been questioned is the initial surge load from a cold start. Here again, the two types of loading can be analyzed separately. The filament power will reach an initial surge value of several times its steady state value because of the low cold resistance of the vacuum tube filaments. This surge current covers a time interval of about one second because of the relatively long thermal lag of the filaments and cathodes. The rectifier load on the other hand usually starts at zero and builds up only as the rectifier filaments heat up. Curves in Figure 2 are for a typical 10-inch television receiver with filament-type rectifier tubes. The initial surge of filament current is about five times the steady

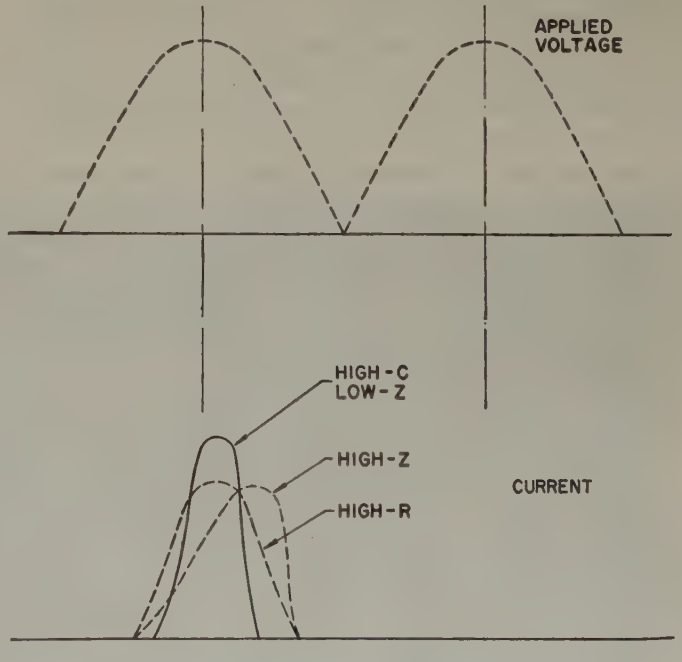

Figure 1. Current flow in rectifiers with shunt capacitor filters

Full text of a conference paper, "Input Power Requirements of Television Receivers," presented at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949.

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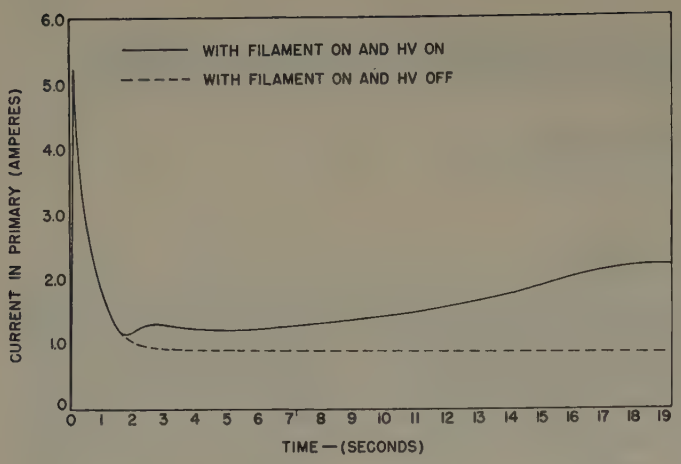


Figure 2. Primary current versus time for a typical 10-inch television receiver

state filament current. Following the filament current surge for about three seconds, there is a small bump in the total current curve; and this represents the current required to charge the various electrolytic capacitors in the plate circuits at a time when the rectifier filaments have started to emit. Following this bump, there is a gradual buildup of plate power as the various tubes reach operating condition; and steady state condition for the complete receiver is reached in about 20 seconds. The steady state current drain of the receiver is not quite half of the initial current surge; and on this basis, the initial current surge on television receivers, in general, will average about twice the steady state current. One additional condition occurs in designs where selenium rectifiers are used; in this case, the plate-circuit charging current represented by the small bump will occur the instant that the receiver is turned on and therefore will be added to the filament current surge. In this type of receiver the initial current surge may be three times the steady state current.

The steady state operating power of television receivers is not as high as might be supposed by judging from the size and complexity of some of the larger models. Television receivers, for instance, cannot match for power consumption such everyday household appliances as electric toasters or electric irons. Television receiver power consumption does vary, as might be expected, rather widely from the smallest 3-inch picture tube type up to the large projection-type home receivers. For power consumption purposes, a television receiver may be considered as a deluxe radio receiver. Since the most common measure of size and complexity in a radio receiver is the number of tubes, the power consumption of radio and television receivers can be approximately charted as a function of the number of tubes. Figure 3 is such a chart made up from data collected from a wide variety of sizes and makes of receivers. The solid curve is for radio receivers and the dotted one for television receivers. The number of tubes in all cases includes rectifier and picture tubes but not selenium rectifiers. As would be expected in a newer art, the variation in power consumption of television receivers is wider than the radio receivers but follows reasonably close to the average curve. There are a number of variables in present television receiver designs which affect this condition and which may be expected to drop out gradually as the more economical designs become standardized. For instance, focusing in a magnetic-type picture tube may be done with permanent magnets or with an electronmagnet. Electronmagnetic focus may require from 10 to 30 watts of additional plate power. Perhaps the greatest single power requirement in television receivers is for magnetic deflection in the horizontal direction. Large amounts of power (up to 40 watts) now are required to swing the electron beam horizontally at a rate of 15,750 scans per second. This relatively large amount of power is not needed because of the actual work done on the electron beam since the actual work is negligible; the energy is used up in the tube and circuit components which are required to generate the very exacting type of variable magnetic field required to retrace the beam in one-tenth of its scan time. Circuits are now in operation in various laboratories and can be expected to appear in commercial receivers which will improve the efficiency of this particular portion of the set very markedly.

The most spectacular portion of the television receiver, that is, the high-voltage supply for the picture tube, does not require as much power as might be supposed. A 10-inch picture tube may operate at an average of about 8,000 volts with an average beam current of about 100 microamperes. This is only eight-tenths of a watt of actual power and even with a rather poor power supply efficiency, total power for this high-voltage supply will run only a few watts. Similarly, 12-inch picture tubes, operating at 10,000 volts and the same beam current, require only one watt; and the most powerful home-type projection tubes operate at 25 kv and 100-microamperes beam current or 2.5 watts actual power.

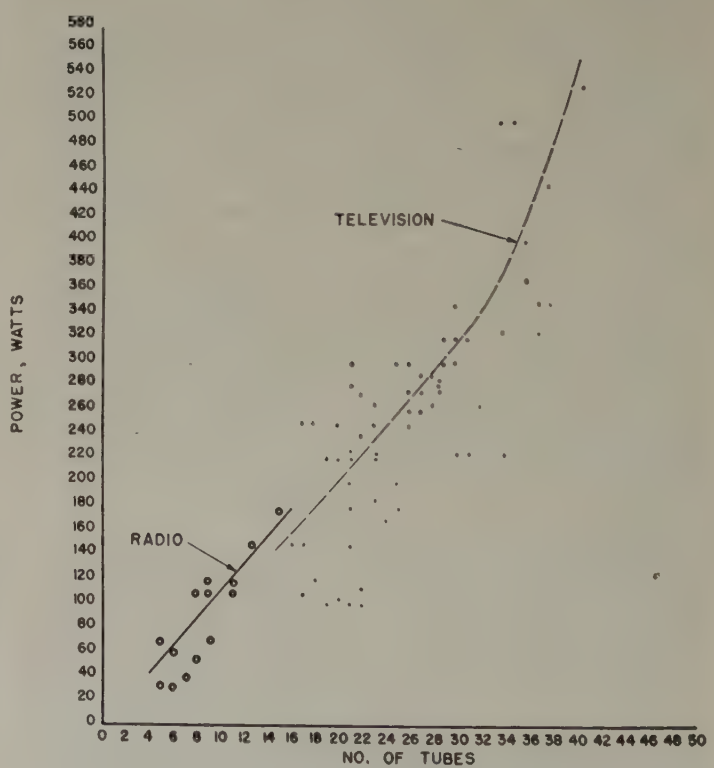


Figure 3. Power consumption of radio and television receivers versus the number of tubes

The data represented in Figure 3 have been charted in another way in Figure 4. Here the power consumption of the variety of television receivers has been plotted against picture size. The horizontal scale is actually picture tube nominal diameter in the case of direct-view receivers and viewing picture diagonal in the case of projection receivers. Here, there is a still greater departure from uniformity between various receivers with the same picture size. This variation represents differences in design as described previously and to some extent represents differences in quality and performance of the various products.

A third variation that is present in the curves of both Figures 3 and 4 is advance in the state of the art. There hardly has been sufficient time as yet to plot a trend of television receiver power consumption against time, but the trend is definitely down and can be predicted along with television receiver prices which gradually are coming down. The two are tied rather closely together because, although prices can be and are being reduced by large scale production and improved manufacturing techniques, a highly developed radio industry already has squeezed most of the water out of that particular sponge. The greater factor in the effort to lower prices will be the improvement and simplification of designs which surely will carry with it a proportional decrease in power consumption.

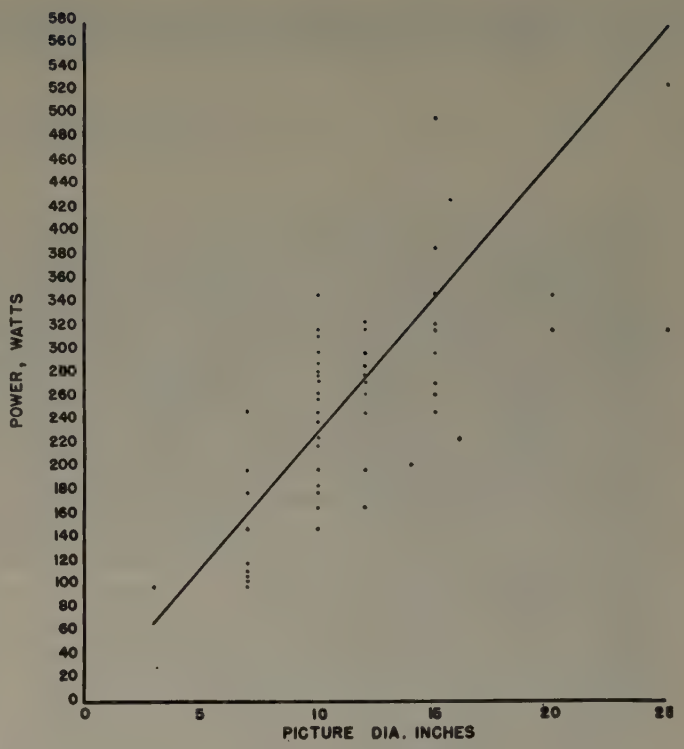
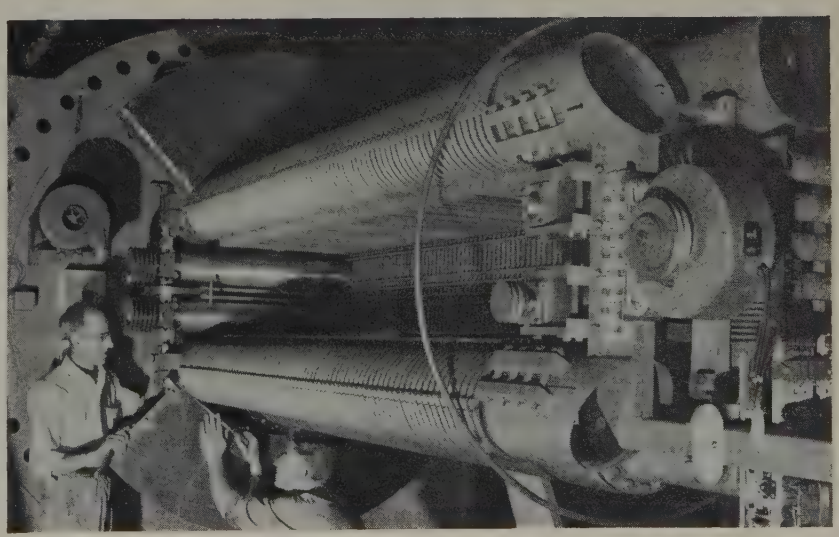


Figure 4. Power consumption of television receivers versus picture diameter

Although it was stated in the beginning of this article that a number of electric power utilities were concerned somewhat about the television power load, it is expected that this condition, even though without a good factual basis is surely temporary and that the electric power utilities are interested in the potential increase in their business. It is estimated that 1,000,000 television receivers are now in use. The average power consumption per receiver is somewhere around 250 watts. This represents a total load of 250,000 kw. Part of this, of course, will be nullified by a decrease in the number of radio receivers in use and a slight decrease in the concurrent lighting load, so that the net load will be somewhat less. Stating this in another way, each new television receiver that is put in use represents perhaps 200 watts of consumer load. Project this to the 10,000,000 television receivers estimated to be in use in the next five years and a 2,000,000 kw consumer load is indicated. This load is of excellent power factor and should be most welcome to an expanding electric power industry.

Electrostatic Accelerator

This 3,500,000-volt electrostatic accelerator, shown in the General Electric Company's general engineering and consulting laboratory, is under construction for use at the Brookhaven National Laboratory, Upton, N. Y. One of several electronuclear machines planned for atomic research, the accelerator will be used for fundamental studies of the atomic nucleus. Though its output energy is considerably lower than the synchrotron, betatron, and cyclotron, it has the advantage of supplying high-speed atomic particles at a uniform energy. Electrostatic charges will be carried from one end of the machine to an aluminum sphere at the other end by two moving belts. When installed, these belts will travel between the two long tubes shown in the foreground. The voltage on the sphere will serve to accelerate a steady stream of protons to a target where the reaction can be studied



Arc Furnace Air-Operated Interrupter Switch

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THE RECENT PROGRESS in the electric arc furnace installation has produced improvements in virtually all phases of the installation with automatic operation and minimum maintenance of the equipment one important goal. Arc furnace switching, which is one important part of furnace operation, is generally well known for the severe duty it imposes on the switching device. Since fault protection as well as automatic switching is required, the practice has been to use a circuit breaker for both switching and protection. However, in order for the circuit breaker to withstand the mechanical duty, it has been necessary to use a circuit breaker especially designed for the purpose. Oil circuit breakers were used originally on arc furnace circuits, but because of the frequency of switching operations the oil deteriorated rapidly by carbonizing, and it was necessary to replace the oil frequently. Unless the oil was replaced, it became very likely that it would fail as an insulating medium when voltage surges appeared. These voltage surges, which are characteristic of arc furnace circuits, make

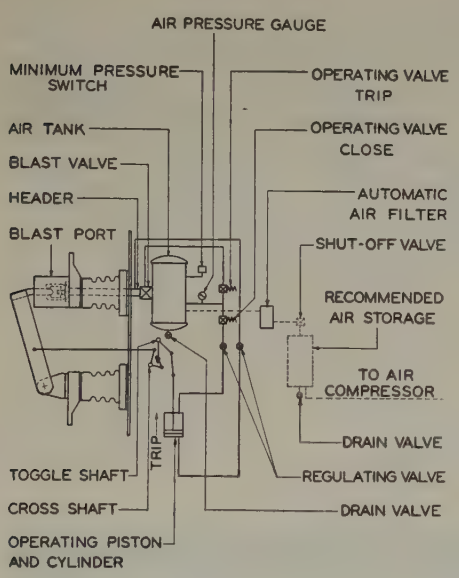

Figure 1. Operating mechanism and air circuit shown schematically

it necessary that the switching equipment for such applications be one voltage class higher than the circuit in which it will operate.

When air circuit breakers became available and were applied to arc furnace switching, the oil problem was eliminated but the special mechanical design was still necessary because of the frequency of operations.

By separating the primary functions of the switching device into the two previously mentioned functions of circuit protection and automatic switching, it becomes possible to use a standard circuit breaker as the protective device and a special switch as the switching device. Thus one circuit breaker can be used to provide the protection for one or more furnaces, as the case may require, and a switching device with each furnace to withstand the frequent switching operations that are required. With this arrangement maintenance will be reduced and reliability will definitely be increased.

A special interrupter switch has been designed, and successfully applied to arc furnace switching. It is an electro-pneumatic operated device, and somewhat resembles the conventional disconnect switch except that it is equipped with air blast circuit interrupting contact enclosures, and a pneumatically operated mechanism. It is rated to interrupt 600 amperes alternating current up to 15 kv. This switch can be operated from the shop supply of compressed air at approximately 90 pounds per square inch. The compressed air, after being passed through an automatic filter, is stored in a tank mounted on the switch. The tank is under pressure at all times, hence the switch is ready for immediate operation. A minimum pressure switch mounted on the air storage tank prevents operation of the switch unless sufficient pressure is available for operation. In the case of a failure of control power, the "operating valves" may be operated manually thus providing means for emergency operation. The interrupter switch and its air circuit is shown schematically in Figure 1.

In Figure 1, the closing operation is initiated by energizing a closing relay through a control switch. This energizes the "operating valve-close," forcing the piston to move to close the switch. The opening operation is initiated similarly, the air from the "operating valve-trip" being directed into a blast valve. This causes the blast valve to open and release air from the tank into a header. From the header, the air rushes through the center of each upper porcelain bushing into the contact enclosures where the circuit is interrupted.

Automatic tripping of the interrupter switch on overloads within its rating may be provided by using the usual overload relays actuated by current transformers in either the primary or secondary side of the furnace transformer. In such cases lockout relays are recommended in order to prevent more than maximum rated interrupting capacity current being interrupted by this switch.

The interrupter switch can be arranged for either wall mounting at a height sufficient for safety, or mounting in a switchgear cubicle of the same dimensions as a standard cubicle. This switch has been specifically designed to withstand frequent use and to be simple in operation, permitting easy inspection, maintenance, and replacement of parts, if necessary.

Digest of paper 48-288, "An Air-Operated Interrupter Switch Applied to Arc Furnace Duty Up to 15 Kv," recommended by the AIEE switchgear committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

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Electric Power for Transporting Natural Gas

W. T. THAGARD

The "Big and Little Big Inch" lines, two of the longest gas transmission lines in America, depend entirely on electric energy for their operation. One two-hundred and eightieth of our entire yearly electric power consumption is used by their many pieces of equipment. The successful conversion of these lines, which originally were built and used during the war for carrying crude oil and refined petroleum products, is described in this article.

THE POWER consumption for the operation of the "Big and Little Big Inch" lines for the transportation of natural gas will exceed the one billion kilowatt-hour figure in 1949. This amount of electric energy will be required in the 21 compressor stations operating on these lines to move approximately 500,000,000 cubic feet of natural gas per day from the Southwest to the Appalachian and Eastern Seaboard areas. The majority of this power will be used in 14 compressor stations where a total of 107 electric motors ranging in size from 1,250 to 2,000 horsepower are used to drive centrifugal gas compressors. These stations have a demand of approximately 126,000 kw and are supplied by nine electrical utilities operating from Texas to Pennsylvania.

In the gas industry 1,000 cubic feet is a commonly accepted unit of measurement, and as a result to speak in terms of millions or billions of cubic feet is quite commonplace, but one billion kilowatt-hours of electric energy is something new. The full significance of this quantity is realized only by some comparison. The total production of electric energy by the electric light and power industry of the United States in 1948 was approximately 280 billion kilowatt-hours. The total estimated power consumption for the operation of the Big and Little Big Inch lines in 1949 is 1,055,400,000 kilowatt-hours. In other words, the operation of these lines for the transportation of natural gas this year will require approximately $1^1/_2$ days' production of the entire electric light and power industry in this country.

The Big and Little Big Inch pipe lines were constructed by the government during the past war to carry crude oil and refined petroleum products from Texas and Louisiana to the Philadelphia and New York areas. The Big Inch line originates at Longview, Tex., and terminates at Linden, N. J. This line consisted of 1,264 miles of 24-inch and 130 miles of 20-inch pipe. The so-called Little Big Inch, a 20-inch line, originated in the Houston and Beaumont, Tex., area, and also terminated at Linden, N. J., and is approximately 1,475 miles long. Both lines were operated with electrically driven centrifugal pumps. The Big Inch line had 27 stations with an installed horsepower of 128,450; while the Little Big Inch had 30 main line stations with 113,800 horsepower installed. To operate the lines with a minimum of personnel they were converged at Little Rock, Ark., and from there the lines are on a common right of way with the pump stations of both lines being on the same site. Although the lines were physically separated and operated independently, the 23 stations north of Little Rock were in reality dual stations. Figure 1 shows the route of the lines and their stations. With the end of the war in 1945, the operation of these lines was discontinued, and the War Assets Administration advertised for bids for their disposal. On May 1, 1947, the Texas Eastern Transmission Corporation took possession of the properties with the intention of operating the lines for transportation of natural gas. The Government included, in the terms of the sale of the property, provisions for its recapture in time of emergency. Under these same provisions the company must be able to restore the property within 90 days to the same operating conditions, ordinary wear and tear excepted, that existed at the time of the sale.

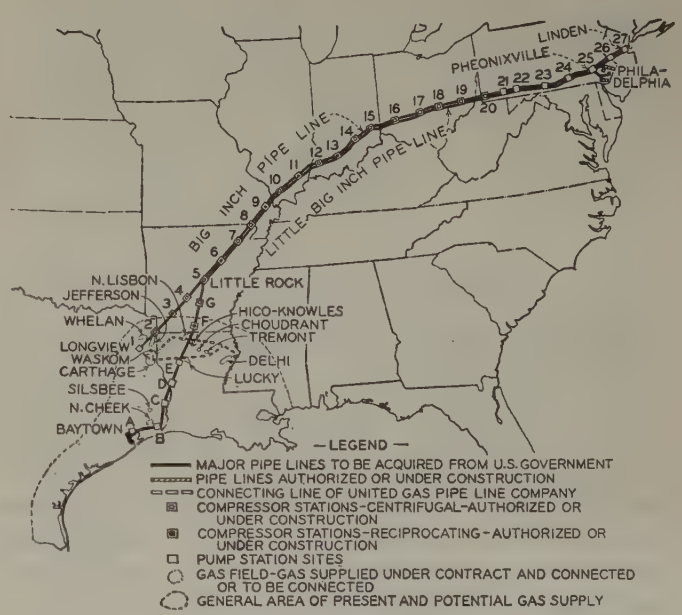

Figure 1. "Big and Little Big Inch" lines

The transportation of gas through these lines presented one of the most unusual problems in the long-distance

Essentially full text of a conference paper, "The Use of Electric Power in the Transportation of Natural Gas through the Former 'Big Inch' and 'Little Big Inch' Oil Lines," presented at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949.

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transmission of natural gas; since the line, already in place, had been designed for the transportation of oil and its products with a definite origin and a definite termination. A study of the map (Figure 1) will show that the lines originate in some of the richest gas reserves in the United States, and terminated in areas which presented perhaps the most attractive natural gas markets in the country. Therefore, having an adequate gas supply and a market for the gas, the problem then was how to move this gas.

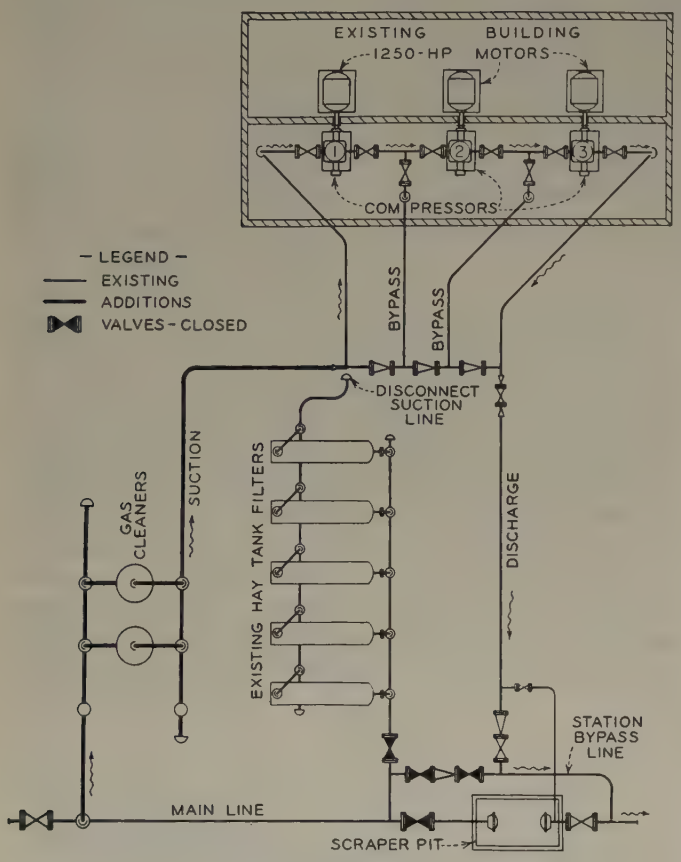

Figure 2. Typical compressor station layout utilizing centrifugal compressors

The lines with their wall thickness determined the maximum operating pressures. With this limitation, studies were made to determine the quantity of gas that could be transported economically through the lines. The original studies were based on the use of reciprocating gas-engine driven compressors without regard to the existing pump-station sites. Being limited to an operating pressure of approximately 750 pounds per square inch, these studies indicated that by operating the lines as a parallel system north from Little Rock, Ark., that the best operation would be at a capacity between 425,000 and 450,000 MCF (thousand cubic feet at atmospheric pressure plus ten ounces) per day. These studies also indicated a station spacing of approximately 50 to 70 miles, and a compression ratio of about 1.35. From these studies it was decided that the compressor stations would be located at the existing pump-station sites since they were spaced approximately 50 miles apart.

In February of 1947 inquiries were made of the engine manufacturers to determine their approximate delivery dates. These inquiries led to a proposal to build a centrifugal compressor using an electric motor drive. Such a proposal was interesting, and immediately appealed to the company, as it presented possibilities of better utilizing the facilities that were being purchased.

The principal electrical facilities included in the purchase were: 86 1,250-horsepower motors, 84 1,500-horsepower motors, and 54 3,750-kva transformers, or a total of 233,250 horsepower in major motors and 202,500 kva in major transformers, with the necessary related switchgear and substation equipment.

An investigation was made of the practicability of using centrifugal compressors with electric motor drives. This investigation revealed many things, among which were

1. Centrifugal compressors had not been used previously for long-distance gas transmission.
2. They had not been used for pressures above 500 pounds per square inch.
3. There was some question as to the ability to obtain a satisfactory seal for this service at these pressures.
4. Considerable progress had been made during the war, both in techniques of their manufacture and the materials that go into their construction.
5. Maintenance and operating cost other than fuel were estimated to be considerably less than for gas engines.
6. The centrifugal compressor is essentially a high-capacity machine.
7. First cost of the compressor and motor with the necessary electric station equipment was in line with other compressing equipment.
8. More gas could be delivered to the market, as no gas would be required for fuel.
9. Economic studies indicated that the price which could be paid for electric power was in the range of that which was paid during the operation of the lines for oil service.
10. The use of centrifugal compressors in conjunction with existing electrical facilities would allow an earlier date for increasing the delivery capacity of the lines.

Management, after consideration of all the factors involved, decided that electrically driven centrifugal compressors would be used. The existence of the electric system, one of the major facilities at each station, was a very important factor in making the decision. The compressors were designed to fit the foundations and piping in the existing pump houses so that the oil pumps could be lifted from their foundations and replaced with the gas compressors. This arrangement established the physical design of the compressors as a double suction unit, designed to operate at 3,600 rpm. By this design the 1,250 horsepower 3,600-rpm 2,300-volt squirrel-cage induction motors from the 20-inch line could be used as direct-connected prime movers. With a compressor design capacity of 225,000 MCF per day, it was determined that a compression ratio of 1.3 could be developed in three stages and the horsepower required would not exceed the limitations of the 1,250-horsepower motors. Therefore, by operating the 20- and 24-inch pump stations in parallel, the capacity

of six single-stage centrifugal compressors would be approximately 450,000 MCF per day with a discharge pressure of 750 pounds per square inch. To operate the lines in parallel each dual station would require a crossover tie on both the suction and discharge side of the station. This meant that practically all of the existing electrical facilities at each station could be utilized with the exception of the 1,500-horsepower motors. Figure 2 shows a typical oil station converted to gas operation of this design. Such a design brought to a minimum the number of changes necessary in the piping and electrical facilities, and required no change in the pump station structure.

A survey was made of the 19 power companies, which formerly provided the electric power, to determine if they could serve the loads that might be required, and what rates would be available for such power. About 18 months had elapsed since power had been required by these lines, and much of the power previously supplied had been sold to other customers. In 1947, most power companies in this country were facing a critical shortage of generating capacity, and many transmission lines were loaded almost to the breaking point. These areas were no exceptions. At some station locations it was determined immediately that power could not be obtained in the quantity and at the time desired, or that the expenditure to get the power was economically unsound. At these station locations, other forms of motive power would be required and it was decided to use reciprocating gas engines. This also would add flexibility to the operation of the lines.

With the necessary information available and major decisions made, it was now time to make the final design for the use of the "Inch Lines" to transport natural gas. The design was for an input capacity of 450,000 MCF per day and a delivery capacity of 433,000 MCF per day. The difference of 17,000 MCF was for engine fuel, and lost and unaccounted for gas. With this capacity, the lines would require a total of 126,280 horsepower distributed along the lines in compressor stations. Of the 21 stations, five would be of the reciprocating type with an installed capacity of 36,000 horsepower and 16 would be electrically driven centrifugal compressors with an installed capacity of 117,500 horsepower. The total installed horsepower capacity of the line would be 153,500.

This design called for three stations on both the 20-inch and 24-inch lines before they converged at Little Rock, and a total of 15 of the dual-type stations. With this design one station on the 24-inch line and four stations on the 20-inch line south of Little Rock would not be used; also, eight of the dual stations on the north end would not be required. This design called for the use of 72 1,250-horsepower and ten 1,500-horsepower 3,600-rpm motors. The 20-inch line had a total of 86 1,250-horsepower motors, therefore, no additional motors needed to be purchased as it was planned to rerate ten of the 1,250-horsepower motors to 1,500 horsepower. With such a design it would be necessary only to move the motors, several switchgears, and utilize the existing transformers, switchgear, and so on. The foundation and shaft design of the 1,250-horsepower motors from the 20-inch line were essentially the same as the 1,500-horsepower motors of the 24-inch line, therefore, making them interchangeable by certain minor modifications of the foundations. It can be seen that the use of electrically driven centrifugal compressors with this capacity design offered a most practical and economical way of converting the "Inch Lines" to a gas transmission line, as about the only thing not used for this conversion would be the oil pumps.

By May 1947, Texas Eastern began operations of the lines, and materials were being ordered and plans for the conversion of the lines were well under way. At this time, natural gas was being introduced at 750 to 800 pounds per square inch and without compression the lines delivered approximately 140,000 MCF daily to the Appalachian area. The construction necessary to bring the capacity of the line to the delivery of 433,000 MCF per day was planned in three stages. The first stage was to increase the deliveries to 265,000 MCF per day by November 1947. This would require the completion of four stations, two centrifugal stations with a total of 15,000 horsepower, and two reciprocating stations with a total of 13,000 horsepower. The second stage was to increase the capacity to 340,000 MCF per day. This would require the completion of one more reciprocating station with 5,000 horsepower and five more centrifugal stations to bring the total centrifugal horsepower to 73,750. The final stage to bring the capacity to the design of 433,000

Table I. Comparison of Capacity Design

Station Number	Location	433,000 MCF Design: Type of Station	433,000 MCF Design: Required Horsepower	508,000 MCF Design: Type of Station	508,000 MCF Design: Required Horsepower	Difference: Required Horsepower
E	Castor, La.	R	4,750			4,750*
F	El Dorado, Ark.	C	3,800	R	3,840	40
G	Fordyce, Ark.	C	3,800	C	6,470	2,670
2	Atlanta, Tex.	C	2,800	C	7,480	4,680
3	Hope, Ark.	R	4,650	R	7,900	3,250
4	Donaldson, Ark.	C	4,220	C	8,190	3,970
5	Little Rock, Ark.	C	8,000	C	14,170	6,170
6	Bald Knob, Ark.	C	7,000	R	15,100	8,100
7	Egypt, Ark.	C	7,000	C	16,280	9,280
8	Fagus, Mo.	C	9,000	C	13,860	4,860
9	Oran, Mo.	R	8,320	R	14,250	5,930
10	Lick Creek, Ill.	C	6,860	C	11,870	5,010
11	Norris City, Ill.	R	8,080	R	13,320	5,240
12	Princeton, Ind.	C	7,000	C	15,420	8,420
13	French Lick, Ind.	R	6,800	R	10,020	3,220
14	Seymour, Ind.	C	7,000	C	16,480	9,480
15	Batesville, Ind.	C	6,800	C	9,540	2,740
16	Lebanon, Ohio	C	6,200	C	13,330	7,130
17	Circleville, Ohio	C	6,200	C	13,250	7,050
18	Crooksville, Ohio	C	4,200	R	8,500	4,500
19	Sarahsville, Ohio	C	4,000	C	3,040	960*
20	Wind Ridge, Pa.			C	9,140	9,140

Station	433,000 MCF Design: Number of Stations	433,000 MCF Design: Required Horsepower	508,000 MCF Design: Number of Stations	508,000 MCF Design: Required Horsepower	Difference: Number of Stations	Difference: Required Horsepower
Centrifugal	16	93,680	14	158,520	2	68,840
Reciprocating	5	32,600	7	72,930	2*	40,330
Total	21	126,280	21	231,450		109,170

* Decrease.
R = Reciprocating.
C = Centrifugal.

MCF per day was scheduled for August 1948. The 433,000 MCF design was estimated to require a power demand of 76,700 kw for the 16 centrifugal stations. By the terms of the gas sales contracts it was estimated that the lines would operate at a 95 per cent design capacity factor. On this basis it was expected that 624,225,000 kilowatt-hours would be required annually.

An option had been given to one company to increase their daily contract capacity by 75,000 MCF; this option, if exercised, would require the capacity of the lines to be increased to 508,000 MCF per day by the end of 1949. Finally, this was agreed upon, and management set December 1948 as the date this delivery capacity was to be available. By this time the first stage to increase the deliveries to 265,000 MCF per day had been completed and the second stage construction which would increase the delivery capacity to 340,000 MCF per day was nearing completion. This meant that now the third construction phase would go from 340,000 MCF to 508,000 MCF per day instead of the original plan of from 340,000 MCF to 433,000 MCF per day. The redesign for the increased capacity is best shown by the tabulation in Table I which shows the comparison of the station power requirements for the original 433,000 MCF to the final 508,000 MCF design.

It is noted that in the design for 508,000 MCF that the total number of compressor stations did not change; however, the location of some stations did change. On account of a change in available gas supply, the use of station *E* near Castor, La., was no longer necessary. The increase in deliveries in the Appalachian area necessitated the use of station 20 near Wind Ridge, Pa. In the original 433,000 MCF design, you will recall there were 16 centrifugal stations and five reciprocating stations. The 508,000 MCF design was for 14 centrifugal stations and 7 reciprocating stations. Station *F* near El Dorado, Ark., and station 18 near Crooksville, Ohio, were changed from centrifugal to reciprocating stations. This was to provide for more flexibility in operations since with these stations the compression ratios could be varied; whereas with centrifugal compressors using constant speed motors, only a relatively constant compression ratio could be obtained. Station 6 near Bald Knob, Ark., also was changed from centrifugal to reciprocating. This was done for flexibility and on account of the general shortage of power in that area.

The change in capacity design in most instances increased the power requirements for the centrifugal stations. This in itself presented a problem, since the initial requirements for power would have been a strain on the existing facilities of most of the power companies. A survey of the nine power companies required to serve the centrifugal station requirements indicated, that by the time the construction program was completed, the power requirements could be met. On account of the shortage of generating capacity, this power was made available with the understanding that in certain peak demand periods of the power companies, some curtailment of the load might be necessary. The type load offered by the centrifugal compressor stations, in general, was attractive to the power companies on account of the anticipated high load factor at which these stations would operate.

While the original design of the line for 433,000 MCF per day necessitated very few changes in either the piping or electrical facilities, the new design of 508,000 MCF per day, however, presented quite a different picture. First, many of the existing compressors would require some modification. This was accomplished by a change in wheel design. Design of the units on order was modified to fit the new capacity. These modifications with increased horsepower drives would allow the unit to handle the increased capacity.

The new design called for a total of 107 motors of the following sizes:

Number	Size, Horsepower
34	1,250
24	1,500
21	1,750
28	2,000

The existing 1,250-horsepower motors were reinsulated or rewound to increase the horsepower to 1,500- and 1,750-horsepower motors, respectively; therefore, taking care of these size requirements but the 2,000-horsepower motors had to be purchased. To get the 1,250-horsepower motors to the shops for rewinding and reinsulating necessitated considerable movement and shifting of motors, as by this time 43 of the total number of motors were already in service.

The question of transformer capacity presented a real problem. For the 433,000 MCF design it was not necessary to move any transformers, as the increased capacity required could be obtained by adding fans to the existing transformers. The 508,000 MCF design was far from being that simple. Transformers, each having a low side voltage of 2,300, that had been purchased with the lines and were available for use, were of the following sizes:

High Side Voltage, Kv	Size, Kva	Number
25	3,750	6
33	3,750	13
33	1,500	1
66	3,750	21
66	2,500	1
66	2,000	1
66	500	1
110	3,750	14
Total		58

The first plan considered was to use three transformers at stations where the load was over 10,000 kw. Under this plan, two transformers were to be located at one pump house and one transformer at the other with a 2,300-volt bus tie between pump houses. A reactor was to be placed in the one single transformer secondary circuit so that the load would balance. When this plan was studied more closely, it was decided to use two transformers at each pump house and to have no bus tie between pumphouse locations. With this plan, stations with a demand over 10,000 kw would have a total of four transformers. With this type of installation each pump house would be entirely

separate from the other electrically, and furthermore each transformer would feed one switchgear.

Parallel operation for each pump house also was investigated thoroughly, and it was found that: more favorable operation would be obtained with separate circuits than with the transformers paralleled as far as the station was concerned, and the interrupting capacity of the incoming line oil circuit breakers in each switchgear was limited to 100,000 kva and in the majority of cases the interrupting capacity that would be required far exceeded this value.

The scheduled movement of transformers from one location to another originally was set up for parallel operation; the idea to match impedances was carried forward even after separate circuits were decided upon so that in the future if parallel operation was ever to be used, no other movements would have to be considered. This necessitated several very long moves of transformers; but to avoid long interruptions in case parallel operation was ever used, it was considered advisable to go through with the original schedule of movements.

In order to accommodate the loads at some of the stations, the 3,750-kva transformers have had forced air cooling added to obtain the necessary additional capacity. There are now in operation nine 3,750-kva transformers using 133 per cent fans, and two transformers using 167 per cent fans.

Where required, the existing substations at each pump house were supplemented by the addition of a steel substation for terminating the second circuit. A total of 21 steel structures were erected. This structure was designed and fabricated to take care of the existing switching equipment that was moved from other locations. Movement of air break switches, lightning arresters, hook switches, and fuse disconnects was based upon the same schedule as the transformer movements. In three cases the existing transmission lines into the stations had to be rebuilt and in one of these cases, the rebuilt line was changed from 33 kv to 66 kv.

The next step in the scheduled movement of equipment was the moving of metalclad switchgear to the points where it was needed. The basis upon which these movements were made was to have starting equipment of the same type and same manufacturer at each location. Where reduced voltage gear had to be sent to stations where full voltage starting could be used, slight modifications changed this gear to across the line starting. The type used at each station depended upon the requirement of the power company's system which supplied each station. There are four stations in operation where reduced voltage starting is used.

The metalclad switchgear is of the lift type, both for reduced voltage and full voltage starting. In all cases the switchgear consists of an incoming line oil circuit breaker with 1,200-ampere capacity and an interrupting capacity of 100,000 kva. The motor starting oil circuit breakers are either 600- or 1,200-ampere capacity with 100,000-kva interrupting capacity. This switchgear is standard metalclad equipment with undervoltage, overcurrent and reverse phase relays, watt-hour meters, recording voltmeter, and other accessories.

While the movement schedules were being set up, the detailed engineering was started. The equipment selected for movement was rated to handle the proposed loads according to the basic plan, but adapting the equipment to new locations presented many problems. Existing facilities that could be used had to be saved, and these had to be closely adhered to in order to avoid too much difference between the existing and new construction. Also the new facilities had to be fitted into the existing plan. The control room of the 20-inch pump houses had to be extended ten feet in most cases to make room for the additional switchgear. The motor and pump rooms had to be extended to house the additional motors and compressors. Since most all of the detailed prints of each existing station facility were available, this engineering could be done without too much detailed field work.

After the detailed engineering was completed, one of the most serious problems was yet to be confronted; this was material. With acute shortage of construction material, the procurement of the necessary items was very difficult. However, most of the required material was obtained from innumerable sources with very little substituting and temporary work. The construction personnel, supervisors, foremen, electricians, linemen, and laborers were recruited from nearly all parts of the country. The fact that the work was spread from Texas to Pennsylvania made it a problem. The material shortage and the man power shortage had to be overcome by moving personnel from one location to another as material became available at the various locations. From the electrical standpoint, the job was broken up into two sections, that east of the Mississippi River and that west of the Mississippi River.

Figure 3. Exterior of typical pump house showing substation

To summarize the electrical installations at the 14 centrifugal stations, Table II shows equipment, transmission voltage, and estimated loads.

Figure 3 shows the exterior of a pump house on the 24-inch line. The original wooden and the new steel substation will be noted. The general arrangement of the building and substation structures is similar at other stations on the lines. Figure 4 is an interior view of a

compressor room. The interior of a motor room is shown in Figure 5. This is a motor room on the 24-inch line. It will be noted that at this pump house the switchgear is in the motor room. This is true for all pump houses on the 24-inch line. On the 20-inch line the switchgear is in a control room located on the discharge side of the pump house.

The first compressor stations for the transportation of natural gas through the Big and Little Big Inch pipe lines were placed in operation in November 1947. During the 12 months ending October 1948, 18 compressor stations, including 11 centrifugal and 7 reciprocating, were put in operation; the delivery capacity of the lines was increased from 140,000 MCF per day to 433,000 MCF per day. During this 12-month period a total of 247,129,590 kilowatt-hours were used in compressor station operation. A maximum demand of 69,750 kw was reached in a common suction and discharge by having crossover ties on both the upstream and downstream side of the station. To bring a station on the line, the crossovers are closed, and the pressures are equalized across both the 20-inch and 24-inch stations. At this time the lines are operating as independent lines. Either one of the stations then is started in the following manner. The seal oil and lubricating oil cooling system is started, then the lubricating and seal oil circulating systems. When these are in operation and checked, the compressor case is pressurized from the suction side. Next the discharge valve is fully opened and the motor is started. As soon as the unit is up to speed the suction valve is opened and the unit is in operation. As soon as the first unit has obtained its full ratio the next unit is started. This sequence is followed until all units are on the line. When all units on both lines are on, crossovers are opened and parallel operation is started.

Table II. 508,000 MCF Per Day Capacity Design Centrifugal Compressor Station Statistics

Station Number	Location	Installed Horsepower	Number and Size of Units, Horsepower	Estimated Kw Demand (Including Auxiliaries)	Estimated Monthly Energy Consumption, Kilowatt-hours*	Transformer Capacity, Kva, Number and Size	Transmission Line Voltage Kv
G	Fordyce, Ark.	7,500	6 1,250	5,166	3,507,197	2 3,750	110
2	Atlanta, Tex.	8,000	4 2,000	5,897	4,003,473	2 3,750	66
4	Donaldson, Ark.	8,000	4 2,000	6,501	4,413,529	2 3,750	110
5	Little Rock, Ark.	15,250	6 1,250 3 2,000 1 1,750	11,242	7,632,194	4 3,750	110
7	Walnut Ridge, Ark.	19,000	6 2,000 4 1,750	12,914	8,767,315	3 3,750(*A*) 1 5,000	110
8	Fagus, Mo.	13,500	6 1,250 4 1,500	11,000	7,467,221	4 3,750	110
10	Anna, Ill.	13,000	6 1,750 2 1,250	9,421	6,395,917	2 3,750(*B*)	69
12	Princeton, Ind.	16,500	4 1,500 6 1,750	12,224	8,298,874	4 3,750(*A*)	66
14	Seymour, Ind.	19,000	4 1,750 6 2,000	13,056	8,863,718	4 3,750(*A*)	66
15	Batesville, Ind.	9,000	6 1,500	7,576	5,143,346	2 3,750(*A*)	34.5
16	Lebanon, Ohio.	14,000	4 1,250 6 1,500	10,583	7,184,799	4 3,750	69
17	Circleville, Ohio.	12,500	10 1,250	10,638	722,138	4 3,750	69
19	Sarahsville, Ohio.	6,000	2 1,500 (2 1,500 standby)	2,442	1,657,874	2 3,750	66
20	Wind Ridge, Pa.	10,000	5 2,000	7,255	4,925,420	2 3,750(*C*)	25
	Total	171,250		125,914	85,483,015	158,750	

* Energy consumption does not include transformer or transmission line losses.

(*A*) Two transformers fanned to 5,000 kva each.

(*B*) Transformers fanned to 6,250 kva.

(*C*) One transformer fanned to 5,000 kva

October. The breakdown between centrifugal and reciprocating stations was

	Maximum Demand, Kw	Kilowatt-Hour Consumption
Centrifugal	67,953	243,038,950
Reciprocating	1,797	4,090,640
Total	69,750	247,129,590

A brief discussion of some phases of the operations of a centrifugal station will explain more fully the use of electric power in the transportation of natural gas through these lines. Each dual station is designed so that either line may operate independently of the other, if necessary. Normally, however, the stations operate in parallel through

One unit going off the line presents an interesting operation. When in full operation both the 20-inch and 24-inch stations are in balance; that is, the same volume of gas is flowing through each station. For a unit to go off means an unbalance of the station, as the line with the most units operating will tend immediately to take all of the gas and, therefore, cause an overload of the motors causing these units to shut down. The quickest way to correct this situation is to shut down the entire station and close the discharge crossover. Then the units are restarted in the manner described. With the condition of one line operating with more units than the other, the lines are operated separately with different discharge pressures resulting. At such times as the unit that originally went off is brought back on the line, the discharge crossover is

opened and then the lines are again in parallel operation.

In the operation of the centrifugal stations, the auxiliary equipment, although small in load comparison, cannot be overlooked. Actually, the seal oil system of the centrifugal compressor is of vital importance. The seal itself is a mechanical seal of the hydraulic type. Oil at a pressure higher than that of the gas being compressed maintains the rotating ring in proper contact with the stationary sleeves. The oil also provides a cooling medium for the seal. Each compressor has its own seal oil system. The seal oil pumps require a 3-horsepower or a 15-horsepower 220-volt 3-phase motor, depending upon the make of the compressor.

In this part of the station equipment, a power failure can be most serious. If the oil pressure becomes less than the gas pressure, the seal will blow. This will do considerable damage to the seal, and the repairs can take a number of hours. The system is so designed that the oil pressure can be retained for about 30 minutes after the seal oil motor pump is stopped. When the seal oil motor stops, a time delay relay is operated to take the unit off the line.

Other auxiliaries at the stations include oil cooling system, lubricating oil system, water well pumps, ventilating fans for motors, air compressor, and motorized valves.

The electric load at each centrifugal station is controlled by an indicating and recording kilowatt demand meter. This is a very important control instrument, and particularly so from a dollar point of view, as a few per cent increase in the kilowatt demand of the entire system can be a staggering figure when converted to dollars. This demand meter is a totalizer for the entire station load. The maximum demand at each station is set by a predetermined calculation. As the load approaches the maximum figure, a warning alarm is sounded and continues to sound until the station operation is adjusted to come within the limit previously set.

This article is largely devoted to the use of electric power in the centrifugal stations on the "Inch Lines." It hardly would be complete without mentioning the use of electric power at the reciprocating stations.

Although a relatively small percentage of the total power is used at the seven reciprocating stations, it is nevertheless just as vital to the transportation of natural gas through these lines, as all auxiliary power at these stations is purchased from electrical operating utilities. These seven stations have a total demand of 2,000 kw with an estimated total annual consumption of 16,289,400 kilowatt-hours. The maximum and minimum station demands are 120 kw and 415 kw, respectively.

To the gas industry the operation of these lines is something entirely new in many respects; it is one of the longest and largest gas transmission lines in America entirely dependent on purchased electric energy for its operation. Not one cubic foot of gas from this line is used in the compressor stations to generate electric energy for its operation. The total load of the system is approximately 128,000 kw. This load is spread among ten power companies; the loads range from 380 to 33,000 kw from each power company. These loads represent only fractions of some company's total load to 40 per cent of one company's load. Without the utmost co-operation from all of these power companies during a period of critical power shortage, the "Inch Lines" today would not be transporting over 500,000 MCF per day of natural gas to a fuel market where natural gas is

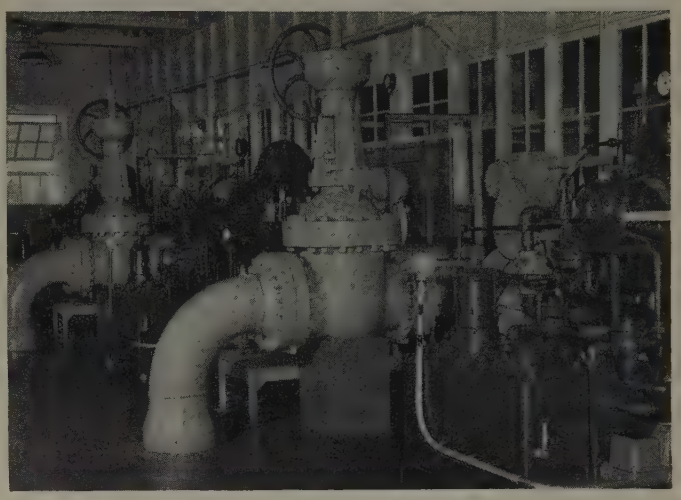

Figure 4. Typical compressor room with centrifugal compressors

practically the life blood of domestic consumers and many industries.

During the war years the "Big and Little Big Inch" lines carrying crude oil and refined petroleum products were using electric energy at the rate of just over one

Figure 5. Typical motor room on "Big Inch" line showing 2,000-horsepower motors

billion kilowatt-hours per year. These lines as now used for the transportation of natural gas are using electric energy at approximately the same rate. This amount of power would supply the annual requirements of approximately 734,000 domestic consumers at the 1947 national average of 1438 kilowatt-hours per domestic customer, as again the lines are "Big" users of electric power.

Stabilized Permanent Magnets

P. P. CIOFFI
MEMBER AIEE

PERMANENT MAGNETS used in apparatus often are subjected to demagnetization by current surges or stray fields. This weakens the magnet and changes the adjustment. Magnets usually are stabilized against such demagnetizing forces by partial demagnetization. Because, under this condition, the magnet operates at a point within the demagnetization curve quadrant, some other criterion of performance must be applied in magnet design. Under stabilized conditions it operates on a curve which is called a secondary demagnetization curve and can be derived from the major demagnetization curve:

(*a*). By an applied demagnetizing magnetomotive force after magnetization in assembly.

(*b*). By magnetization of the magnet before assembly in its magnetic circuit.

The secondary demagnetization curve then may be treated identically as the major demagnetization curve.

For case *a*, Figure 1, the magnet cycle is as follows: After applying and removing a magnetizing force sufficient to saturate the material, the magnetization drops to the point *P* which is determined by the intersection of the load or air-gap line *OP* with the demagnetization curve. An applied demagnetizing force H_d diminishes the magnetization to the point *Q*, determined by the intersection of the line QH_d drawn from H_d parallel to the air-gap line *OP*. Upon removing the demagnetizing force H_d the magnetization proceeds along the lower branch of the minor hysteresis loop to *Q'* on the air-gap line. Upon reapplication of the demagnetizing force H_d, the magnetization diminishes along the upper branch of the minor loop back to *Q*. The slope of the line connecting the tips of the minor loop, *QQ'*, is a measure of the reversible permeability of the material. The magnetization represented by the point *Q'* is stable to any temporarily applied demagnetizing force not exceeding H_d as minor loops are reversible.

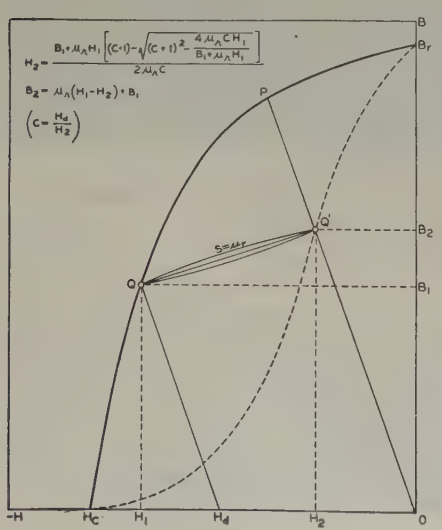

Figure 1. Stabilization by demagnetization with a given magnetomotive force

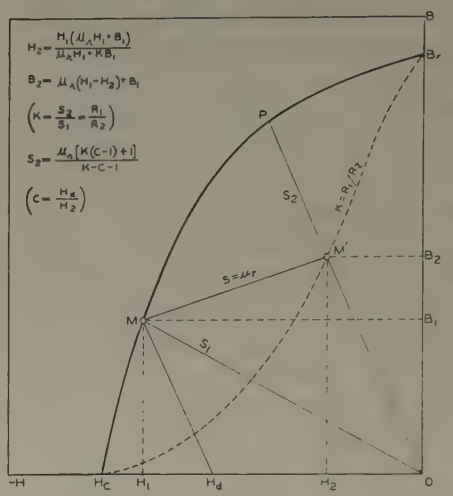

Figure 2. Stabilization by magnetization before assembly

The magnetic cycle for case *b* is illustrated in Figure 2. After removing a magnetizing force sufficient to saturate the magnet, its magnetization may be represented by *M*, given by the intersection of the out of assembly air-gap line *OM*, of slope S_1, with the demagnetization curve. Upon assembly in the magnetic circuit, the magnetization proceeds to *M'*, the intersection of the minor loop with the closed circuit air-gap line, of slope S_2. H_d in this case is the maximum demagnetizing force for which the magnet is stable, given by the intercept on the *H*-axis of the line MH_d drawn from *M* parallel to the air-gap line *OP*.

The locus of the operating point of the magnet for the two methods, as the air-gap line slope changes from zero to infinity, is a curve passing through H_c and B_r which is called the secondary demagnetization curve.

The solution of equations in Figures 1 and 2 give expressions for the co-ordinates of points on the secondary demagnetization curve in terms of the co-ordinates of points on the major demagnetization curve, the reversible permeability, and a parameter. By taking successive values of B_1 and H_1 on the major demagnetization curve, corresponding values of B_2 and H_2 are determined and the secondary demagnetization and energy-product curves may be drawn. For case *a*, Figure 1, the parameter *c* is the ratio of the demagnetizing field to the operating field and is a measure of the degree of stability. The secondary demagnetization curve so obtained has constant stability. For case *b*, Figure 2, the parameter *k* is the ratio of the open circuit reluctance R_1 to the closed circuit reluctance R_2 and the degree of stability is variable for all points on the secondary demagnetization curve. The operating point on this curve giving the required degree of stability is found by intersection with an air-gap line of appropriate slope.

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Evolution of the Modern Automatic Iron

B. F. PARR

From the first crude electric iron manufactured almost 50 years ago, the automatic iron has come a long way to the streamlined iron with adjustable temperature controls that we know today. The evolution of the modern automatic iron, in performance, heating efficiency, temperature control, and styling, is considered in this article.

WHEN MAN gave up fig leaves for skins and, later, fabrics, garments came to assume more than a protective function. They began to be decorative as well. That introduced the problem of removing wrinkles that has been with us ever since. Early methods included stretching, beating, and packing folded cloth under heavy weights.

At some indeterminate time in the Middle Ages it was discovered that if cloth was moistened and then heated under pressure the fabric would be wrinkle-free when dry. What they had discovered without knowing exactly what was happening was that the textile fibers become plastic when wet and can be shaped as desired under pressure and retain that form when dry. This is, in short, the present technique of ironing.

From this discovery sprang the earliest iron which was simply a cast iron shoe with a smooth bottom surface and a handle. Those irons were heated from an external source such as the top of a stove. Many still can remember the old detachable handle sad irons with one iron heating on the stove while another was in use. The term "sad iron" which is still frequently used, actually means heavy iron; heavy is an obsolete meaning for the word sad.

Various means of providing self-heating irons were tried, including charcoal irons, kerosene irons, and gas irons. Then about 50 years ago, with electric wiring of homes becoming common, the first electric irons were introduced.

The first electric irons were crude by present-day standards—they were little different in appearance from top-of-stove irons. The cast base was made in two pieces with a heating element of resistance ribbon insulated with mica sandwiched between. An iron manufactured by the Westinghouse Corporation in 1907 is shown in Figure 1.

Early irons weighed seven to nine pounds with the wattage varying from 375 to 650. Wattage was limited by the capacity of electric wiring of that time and also by the resistance material available. Better resistance alloys soon came, making greater wattage possible but it was found that any appreciable increase resulted in danger of overheating and fire hazard. Most iron manufacturers settled on a 550-watt 6-pound iron as a compromise between ironing performance and safety.

As wattage was limited, at least six pounds of weight was needed to provide heat storage because for many ironing loads 550 watts are insufficient. Ironing was largely guess work since the iron was frequently too hot for light fabrics and too cold for heavy damp linens.

For about 20 years irons were improved but little except in appearance and details. The top casting was covered with a drawn steel shell, usually nickel-plated. Handles were made more comfortable and cord attachments improved. Also some form of support, usually a heel rest, was provided to keep the hot sole plate off the board when not in use. This latter was a safety feature but unfortunately too often the iron was left flat on the board with many resulting fires.

THE AUTOMATIC IRON

In 1924 the first real advance was made toward ironing efficiency and safety with the introduction by Westinghouse of the so-called automatic iron. This iron had a fixed temperature thermostat so was not automatic in the sense used today, but was only a temperature limiting iron.

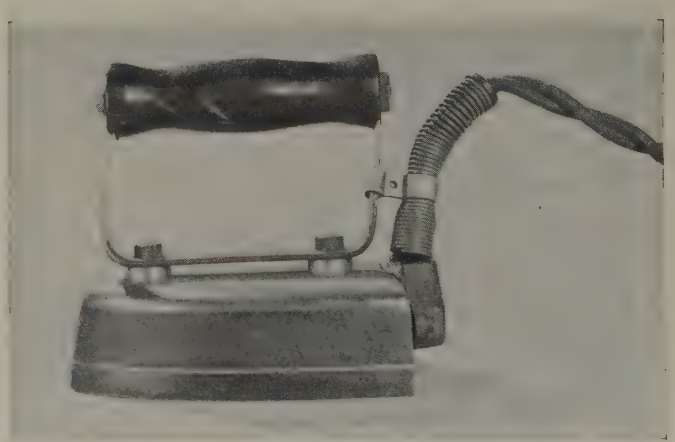

Figure 1. An electric iron made by Westinghouse in 1907

With this iron the temperature of the sole plate should

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Figure 2. Setup for running a calorimeter test on an electric iron

not exceed a factory set limit of approximately 600 degrees. Wattage was increased to 600 and 660 but could not be increased beyond this, otherwise the iron would heat too quickly and scorch light fabrics. Even so, the user frequently had to disconnect the iron to keep it cool enough for silks and light wools and cottons.

The addition of adjustable temperature control followed a few years later. Now the user could select ironing temperature in accordance with the fabric being ironed. True, the early adjustable irons had a controllable range of only about 100 degrees, but this was far better than before. Soon this range of adjustment was expanded downward to 200 degrees and then to 300 degrees bringing the controlled temperature down to that safe for synthetic fabrics.

Wattage now could be increased safely. By 1932, 1,000-watt irons appeared. With increase in wattage, heat storage was no longer so important and weight could be decreased. Weight dropped to 5, then $4^1/_2$ pounds, and finally to 3 pounds.

The improvement in safety of the automatic iron over the nonautomatic was so pronounced that effective in 1940 the Underwriters' Laboratories, Inc., discontinued listing the nonautomatic variety for domestic use. According to the fire record reports of the International Association of Electrical Inspectors, the electric flat iron fires compared to all reported fires of electrical origin for a selected group of cities dropped from 13.2 per cent in 1932 to 2.3 per cent in 1944. There are still a number of nonautomatic irons in use but their number is decreasing each year.

Through the development of automatic controls until the middle 30's, the iron itself remained essentially unchanged in appearance and construction. Chromium plating had entered the picture making the finish more tarnish-resistant and giving the iron more sparkle on the sales counter. However, the heating element still was clamped between two castings, the upper one merely reduced in weight in the lighter irons.

MEASURES OF IRON PERFORMANCE

Engineers now began to look more critically at the performance of irons. The first practical standard test for iron performance was developed by the Electrical Testing Laboratory and later adopted with minor modifications by the National Electrical Manufacturers Association committee on iron standards. This test consists of a calorimeter which allows sole-plate temperature to be measured under load.

In the test, the iron rests on a platform separated from the top of an insulated copper tank by an oil film adjustable in thickness. Water with a constant pressure flows through the tank and by measuring water flow, inlet and outlet temperature the heat extracted from the sole plate can be computed.

Six thermocouples are inserted in holes drilled in the sole plate at prescribed locations. The average of the six is taken as the sole-plate temperature. Sole-plate temperature is determined at idling or no load and at several different calorimeter loads approximately equally spaced until the load exceeds the rating of the iron, whereupon the control no longer functions.

The performance of an iron typical of the construction of the early 1930's is shown in Figure 3. The drop in sole-plate temperature from idle to full load is approximately 120 degrees Fahrenheit. In some irons this drop was as much as 250 degrees.

Some form of actual ironing test to supplement the calorimeter test is also desirable. Since the calorimeter shows stabilized conditions at a constant load, additional information can be gathered with a constantly varying load as is encountered with wet cloth. One such test utilizes 24 cotton muslin cloths 13 by 36 inches of a standard weight. They are moistened first to 20 per cent increase in weight, then 30 per cent, 50 per cent, and finally 75 per cent. With the iron set at a fixed temperature each cloth is ironed 45 seconds and the iron placed on its heel

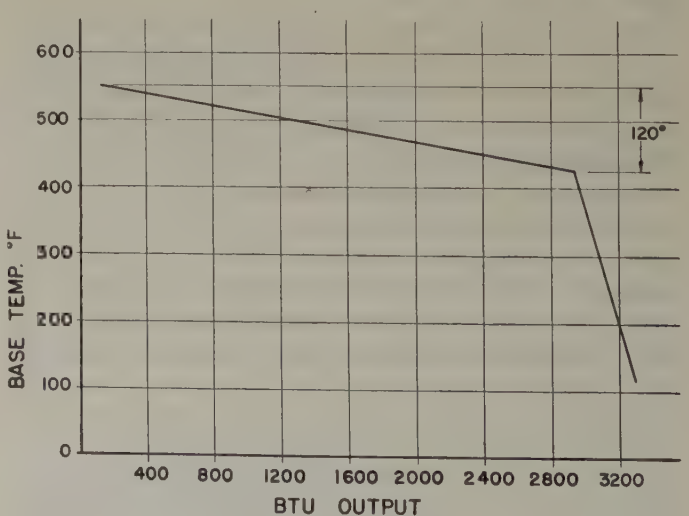

Figure 3. Calorimeter performance chart of a 1932 iron

rest for 15 seconds while the cloth is changed. During a test which requires 24 minutes, the watt-hour input is recorded and the sole-plate temperature recorded on an automatic potentiometer. After the test the cloths are weighed to determine percentage of moisture removed. The ironing chart for the iron used in Figure 3 is shown in Figure 4.

HEATING ELEMENT DESIGN

The tests bring out obvious deficiencies in the old style irons. To provide an adequate ironing temperature for damp heavy fabrics it was necessary to calibrate the control 100 degrees or more high. Then there was danger of scorching lightweight cloth with little moisture added.

With accurate means available for evaluating iron performance in the laboratory, engineers went to work and by close attention to over-all design and proper relation of parts, vast improvement has been made in recent years. The old element assembly was obviously inefficient. Too much heat went into the upper structure of the iron, being not only a waste but also a nuisance in the discomfort to the user. It also allowed poor control response.

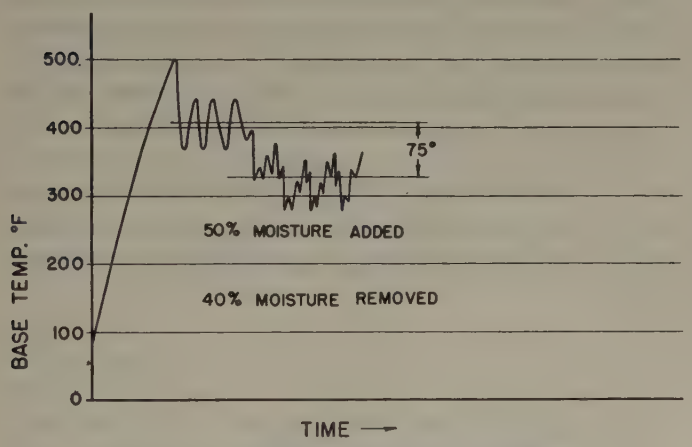

Figure 4. Ironing test chart of a 1932 iron

The first requirement is to obtain proper utilization of heat. This is done by placing the heating element within the base instead of on top of the base. Several constructions were devised to accomplish this. In one, a mica element of the usual type is placed in a recess in the iron base. Then a steel plate is pressed over the element into the recess under several tons pressure, and while still under pressure, it is staked or welded in place. Another type was a helical coil element centered in a groove in the casting and surrounded with a ceramic insulating cement.

A third type, and the one currently most popular because of its long life and efficiency, is the use of a tubular element cast directly into the base. The tubular element consists of a formed steel tube in which is centered a helical element imbedded in magnesium oxide insulation. This follows electric range heater construction.

These types of heating elements give an improvement in calorimeter performance of 30 to 60 degrees as measured by decrease in drop of base temperature without change in the control itself. The cast-in assembly gives the greatest degree of improvement.

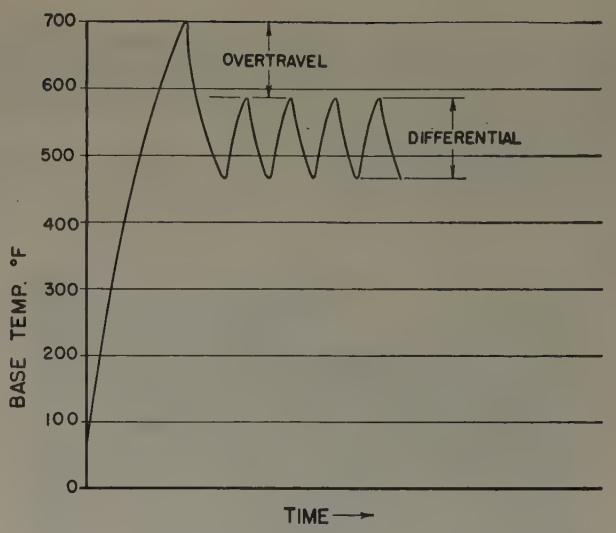

Figure 5. Temperature chart of a 1930 electric iron

CONTROL DEVELOPMENT

In early automatic irons, response of the control to changes in base temperature was poor. From the first introduction of the automatic iron, bimetal has been the thermally responsive element used in the control. At first, the prime requisite of a control was temperature limitation. Since in the 1920's there was still considerable direct current in use, controls were designed for use on either alternating current or direct current which required a positive snap action and good contact separation. Such factors as temperature overtravel on the first cycle, differential between on and off temperature, radio interference, and ironing performance were secondary.

Snap-acting bimetal disks were used in some early controls. These were relatively inexpensive and reliable but had a number of disadvantages. As it was not possible to get a close contact between the bimetal and the base, overtravel on the first cycle was approximately 100 degrees and differential between on and off also around 100 degrees, as shown in Figure 5. Very poor performance as measured on the calorimeter and ironing test resulted. Some correction in overtravel and differential was made by incorporating small auxiliary heaters in the thermostats to heat the bimetal more rapidly. This overcame the objectionably wide differential and overtravel but did not actually improve basic performance.

Another type of snap-acting control was obtained by using a spring toggle in connection with a simple bimetal strip. This control had less overtravel and narrower differential and resulted in improved performance.

With the virtual disappearance of direct current in all but a very few localities it became possible to design irons for alternating current only and provide irons designed for direct current for those districts requiring them. With the necessity for positive snap and wide contact separation eliminated, slow make and break thermostats came into general use and are the type used today. In this control,

a bimetal strip deflects with increase in temperature and opens contacts which normally are spring-biased to closed position. To prevent too rapid cycling or fluttering the bimetal itself does not carry current.

To obtain quick response to base temperature changes, the thermostat bimetal should be in as close contact as possible to the base and be shielded from receiving heat

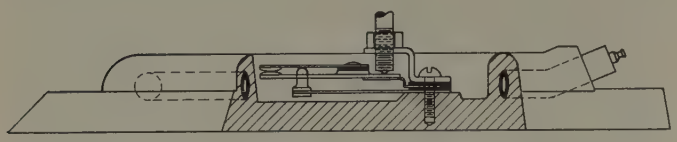

Figure 6. Good practice in iron thermostat application

directly from the heating element. Figure 6 illustrates a modern iron control properly located in the base.

Improvement in calorimeter performance by good control design and application is shown in Figure 7. The drop in sole-plate temperature from idle to full load has been reduced to 20 degrees. To the user of the iron this means that with the dial set for a certain fabric, the average temperature varies but little whether the material being ironed is light in weight or heavy and whether only slightly dampened or quite wet. Also shown on this chart is a calorimeter test for a 1932 iron for comparison. With the same base temperature at full load the 1948 iron has a 100 degree lower temperature idle. This is further brought out by the ironing test chart, Figure 8. This figure also shows the marked reduction in overtravel and differential. An overtravel of 50 degrees or less is not objectionable and a differential not exceeding 50 degrees cannot be detected by the user.

IRONING TEMPERATURE

The heaviest domestic ironing task can be done with a sole-plate temperature of 450 degrees and a weight of three pounds. With poor calorimeter performance as noted on early irons it was necessary to provide idle temperature of 550 degrees to 600 degrees to insure an adequate ironing temperature under heavy load. For the properly designed iron an idling temperature of 475 degrees is sufficient. This, in addition to giving the user uniform temperature over a wide range of load, is another advance in safety. Every step downward in idling temperature of the iron means less chance of fire hazard in cases of improper use.

The widespread use of synthetic fabrics has made it imperative that the range of adjustment on the control be adequate. Any of the present-day fabrics can be ironed without damage at 275 degrees and with the modern iron an adjustable range of 275 to 475 accommodates all types of ironing. To allow for manufacturing tolerances in large volume production, a nominal range of 250 to 500 is suitable.

IRON WEIGHTS

To achieve the desired light weight of about three pounds in a full size iron of approximately 27 square inches sole-plate area and still maintain uniform heat distribution, aluminum is being used for the sole plate instead of cast iron. Aluminum combines high thermal conductivity with light weight and can be polished and buffed to a smooth ironing surface without the addition of plating. It does have the disadvantage of being relatively soft but normal ironing even over pins and snap fasteners does not cause scratches sufficient to catch cloth. Aluminum also loses its original high luster which chromium-plated cast iron does not do. However, this in no way impairs its ironing efficiency.

Most homemakers when they give the 3-pound aluminum iron a trial have no wish to return to heavier irons. There is still some resistance, however, to both the light weight and the use of aluminum. Some prefer the harder cast iron sole plate, feeling that it will be more durable and scratch resistant, and some because of the higher luster of the chromium finish. Many, who have been accustomed to the heavier irons of the past, feel that an iron so light cannot do a good job. It is interesting to note that the preference differs with geographical location. The South buys a larger percentage of heavy irons while in the north the situation is reversed. It is the general feeling in the industry that the trend is definitely toward lightweight irons and that they will account for an increasingly large portion of sales. In the meantime, many manufacturers offer both a 3-pound aluminum base iron and one of 4 or $4\frac{1}{2}$ pounds with a chromium-plated cast iron base.

STYLING MATCHES PERFORMANCE

Along with technical advances has gone vast improvement in styling. In the early and middle 30's, industry

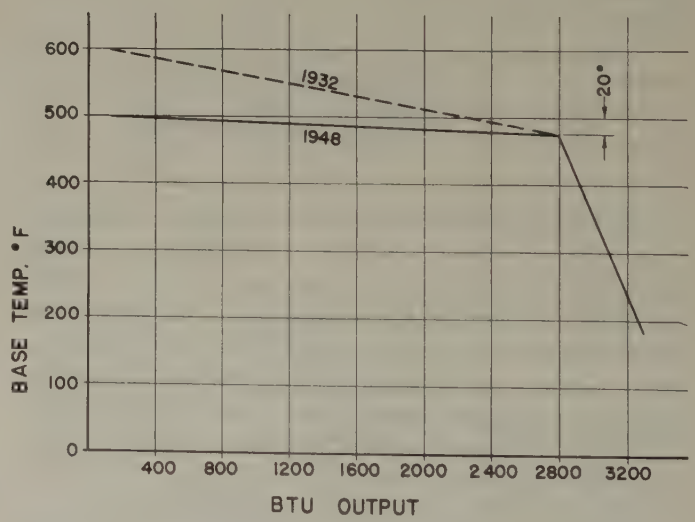

Figure 7. Calorimeter chart for a 1948 iron versus a 1932 iron

in general became increasingly style conscious. D. L. Hadley, at that time commercial designer for Westinghouse, evolved a streamlined treatment for the handle and cover of the iron which established a new trend. This iron was a distinct departure from the traditional flatiron design.

A molded plastic handle provided more comfortable

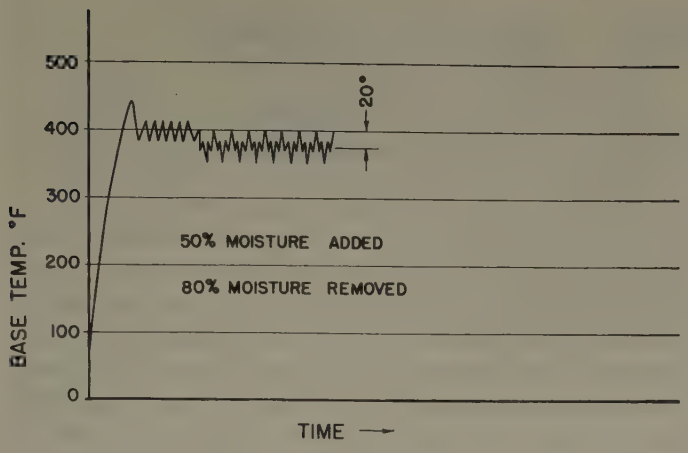

Figure 8. Ironing test chart for a 1948 iron

hand grip as well as giving smooth flowing lines to the top of the iron. The cover, control knob, and cord attachments were restyled in keeping with the handle and in addition to enhancing the appearance, balance and feel were improved thereby.

Further developments include the use of colored plastic, and extension of the plastic handle to form a heat shield for the hand. Figure 9 illustrates a 1948 iron combining all the technical improvements outlined, together with up-to-the-minute styling.

The modern iron is no longer a group of parts; base, element, control, cover, and handle stacked up. To achieve the performance and appearance which today's homemaker expects requires close co-operation of the engineer and designer. The sole plate, element, and control must be co-ordinated to produce the fast uniform heating, quick response, and close control outlined previously. The upper structure must utilize the right materials and design to keep cool temperatures where touched and to provide hand comfort and prevent ironing fatigue.

Figure 9. A 1948 iron showing latest design trends

The first half century of the electric iron is behind us. We have today irons which seem to be the "last word." Undoubtedly the developments of the next 50 years will prove that we are wrong.

Two Electrical Essays

Thevenin's Theorem

THEVENIN'S theorem can be stated as follows: "With respect to any single external circuit connected to any given pair of terminals of a network, the network can be replaced by a single branch having an impedance, Z, equal to the impedance measured at these terminals looking into the network when all the network electromotive forces are made zero, and containing a single electromotive force, E_0, equal to the open-circuit voltage of the network across the given pair of terminals."

A student is given a network shown in Figure 1, composed of a source of direct voltage, a box containing two resistors and two rectifiers, three switches, a voltmeter, and an ammeter. The student does not know the values of the resistances and he is asked to represent the network by the use of a single direct voltage and a resistance which is in series with it.

The student first closes switch *1* and reads 100 volts on the voltmeter. He then opens switch *1* an closes switch *2* making the network electromotive force zero. Next he closes switch *3* to the right connecting the network terminals to a source of 100 volts direct current and reads 100 volts on the voltmeter, and one ampere on the ammeter. He computes the impedance, Z, to be a resistance of 100 ohms. The equivalent network then is represented by an electromotive

force of 100 volts direct current and a resistance of 100 ohms. The foregoing network, when it has been short-circuited, would force a current of one ampere through the short circuit.

In order to check his calculations the student opens all the switches. He closes switch *1* and reads 100 volts on the

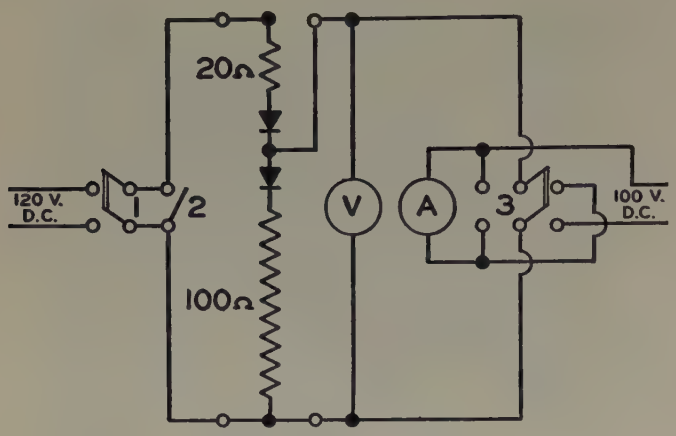

Figure 1

voltmeter. He then short-circuits the network through the ammeter by throwing switch *3* to the left. To the student's amazement and dismay the ammeter reads six amperes.

What is wrong? Is Thevenin's theorem wrong after all? Or is there something wrong with the test procedure followed by the student?

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Magnetic Speedometer for Aircraft

A horizontal metallic rod, moving parallel to the earth's surface, in a direction perpendicular to itself, has induced in it, due to its motion in the earth's magnetic field, an electromotive force $V=10^{-8}\,Hlv$ volts, where H is the vertical component of the earth's magnetic field, in gauss, l is the length of the rod in centimeters, and v is the velocity in centimeters per second. If the rod makes an angle θ with the direction of its motion, then the electromotive force is $V=10^{-8}\,Hlv \sin\theta$. If $l=100$, $v=100$, corresponding to 3.6 kilometers per minute, and if $H=0.1$, which is less than the magnitude of H for latitudes greater than 15 degrees north, and if $\sin\theta=1$, then $V=10^{-5}$ volts, a quantity which is readily measurable through the utilization of modern electronic instrumentation.

This effect then can be utilized for measuring the speed of an aircraft. It, of course, will give the speed of the craft relative to the earth itself, since winds or air motions generally do not affect the earth's magnetic field. This is a great advantage over other methods, using Pitot tubes or other aerodynamic instruments, since these give the craft velocity relative to the adjacent air; side drift, head, or tail winds make such velocity relative to the air of little value for accurate navigation.

The electromotive force induced in the rod probably can be determined best by cutting the bar at its middle and placing the potential measuring device there. We may increase the capacity to space at the ends of the rod by attaching large plates or spheres there. Then most of the induced electromotive force will appear as voltage across the central gap in the rod.

It probably will be advantageous to rotate the rod at moderate speed about a vertical axis. This will make the voltage across the central gap alternating, and will make easy the problem of obtaining enough insulation resistance there. Also it is found much easier reliably to amplify a small alternating voltage than it is to amplify a direct voltage.

If the position is noted where the rotating rod has its maximum induced electromotive force, then the direction of absolute motion of the craft may be determined, and thus also the amount of side-drift observed.

Access to the terminals of the central gap in the rotating rod would be obtained by slip-rings, of course.

Values of the earth's magnetic field are observed regularly by the United States Department of Terrestial Magnetism, and maps are issued at frequent intervals. As this invention comes into general use, we may expect these observations to be taken more frequently, more accurately, and at more closely spaced points.

Is this invention sound?

Answer to Previous Essay

The following is the author's answer to his previously published essay, "Spark-Gap in Wonderland" (*EE, Mar '49, p 245*).

No, such spark-gaps exist outside of Wonderland. One such could have been found in 1931 in the laboratory of the illustrious gas discharge physicist F. M. Penning at the research laboratory of the Phillips Company[1] at Eindhoven, Holland. The gas was helium, with other details very much as Alice saw them.

For explanation, Doctor Penning states that the probability of ionizing a molecule by collision with an electron of varying kinetic energy increases from zero at the ionizing energy of the molecule to a maximum, at a few times the ionizing energy of the molecule, and then this probability decreases as the kinetic energy of the electron is increased further. Under the circumstances which Doctor Penning discovered, the increase in voltage applied to the spark-gap increased the energy of collisions with molecules by the electrons, lessened the production of ions by these collisions, and thus caused the discharge to go out. On lowering the spark-gap voltage, the reverse took place, and the discharge struck.

REFERENCE

1. *Proceedings* of the Royal Academy of Amsterdam, volume 34, 1931, pages 1303–13.

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Electronic Digital Counters

WARREN H. BLISS
MEMBER AIEE

Recent advancements in all branches of science have created demands for high-speed counting devices. The development of the electronic digital counters, which are used for many purposes in the large computers, has made such fast computations possible. These counters, which use the binary system, are described in detail in this article.

THE PROCESS of counting or enumerating objects is, no doubt, as old as civilization itself, but the ability to count individual items at the rate of a million or more per second has been achieved only recently. Mechanical and electromechanical counters usually find an upper limit before the speed of 1,000 per minute is reached. The application of electronic circuits in this field has increased this limit well over 10,000-fold.

The basic process of counting, as we all know, consists of enumerating items one by one for the purpose of determining the total number in a given group. This process leads directly to other kinds of measurements. For example, the speed of a train can be determined by counting the number of rail joints or telegraph poles passed per unit of time. Time intervals also can be measured by use of the counting technique, as the swings of a pendulum can be counted from the beginning to the end of the interval.

A demand for higher counting speeds results from advancement made in the many branches of science. We are striving continually for higher speeds of moving bodies, greater distances into interstellar space, and finer resolution in submicroscopic studies. The art of making suitable measuring instruments must keep in step with such advancements.

MECHANICAL COUNTERS

Before considering the details of electronic counting circuits, certain mechanical counting devices and basic principles well may be considered. A well-known device of this character is the portion of an automobile speedometer which shows the number of miles traveled. Perhaps a better example of a mechanical device which illustrates the basic counting principle is the ratchet wheel and pawl. In this machine the idea of a multiplicity of stable states is well illustrated. The ratchet wheel has as many stable states as it has teeth, and the detent or "holding dog" will keep it at rest in any one of these states or positions indefinitely. The "counts" fed in by the pawl are accumulated one by one and the total at any time is indicated by the wheel position relative to its starting point. This typifies the ideal counter which receives counts uniformly or randomly at any rate up to its upper limit of speed.

In electronic counters the binary circuit is used extensively. This has two stable states and as the counts or pulses are applied, it trips alternately back and forth between these states. A good mechanical analogy of this is the chain-pull switch commonly used on electric lamps. As the chain is pulled, the lamp circuit alternates between its two states of being open or being closed. Two pulls of the chain complete one cycle of events.

A binary group of three switches could be arranged to have eight stable states. To set up such an arrangement, the circuit of the first switch and lamp would include a solenoid or magnet to pull the chain of the second switch and lamp. In a similar manner, the third switch would be controlled from the second. If the zero or starting condition occurs when all three lamps are on, two pulls on the first chain will turn out the second lamp, four pulls will turn out the third lamp, and seven pulls will leave all three lamps out. It is evident that the condition of the lamps will tell how many pulls or counts have been applied, and the entire cycle of events will be repeated for each group of eight applied impulses. Such a system has little practical value but it illustrates the binary-chain principle.

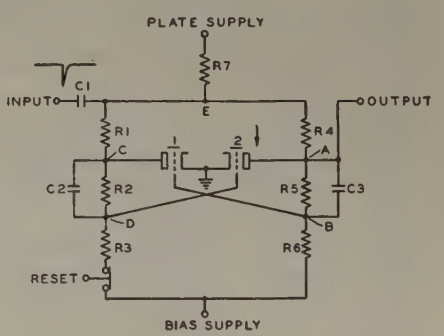

Figure 1. Locking-type multivibrator

ELECTRIC COUNTING ELEMENTS

In searching for electric circuits suitable for counting purposes, the use of capacitors for storing charges appears at first to be a promising possibility. Steps of equal charge can be fed into the capacitor and its potential difference then would be a measure of the number of counts it had received. Although this principle is successfully used as a frequency divider, it is not satisfactory for all counting purposes because of leakage difficulties. The major part of leakage of charge is due to the auxiliary circuit components which must be included for stepping and indicating.

A device is needed which has stable states that will hold

Essentially full text of a paper presented at a meeting of the AIEE New York Section, December 11, 1947.

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indefinitely. A basic circuit of this character has been known for about 30 years. It is shown in Figure 1 with a few added features. In this circuit of two triodes, the cross coupling between plates and grids causes the system to be stable only when one section is conducting and the other is cut off. If the right-hand triode *2* is conducting or on, then its plate (point *A* in circuit) will be at a relatively low potential, while the plate of section *1* will be high due

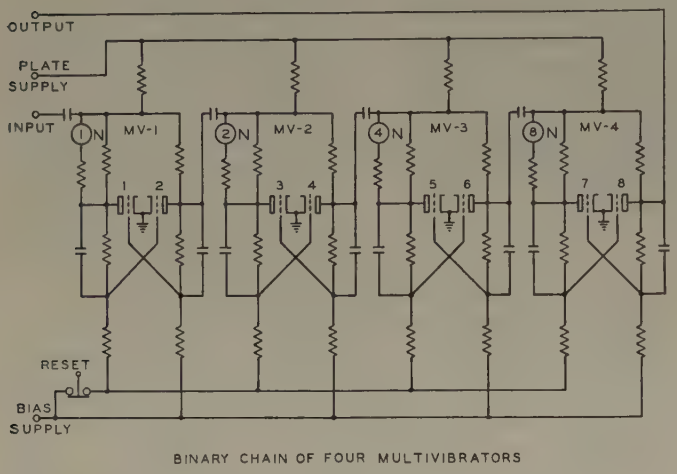

Figure 2. Binary chain of four multivibrators

to nonconduction. Point *A* being low will allow point *B*, which is the grid connection to triode *1*, to be low enough in potential to produce cutoff in triode *1*. At the same time point *D* is held relatively high because *C* is high, and since *D* is connected to the grid of triode *2*, conduction will take place here. In a well-designed circuit this condition is very stable since triode *1* is biased well beyond cutoff and triode *2* is held conducting with its grid slightly positive. Since the circuit is symmetrical, the other mode or state, with triode *1* on and triode *2* off, is equally stable.

Assuming again the initial condition of triode *1* off and triode *2* on, the action when an input driving pulse is applied will be investigated. In the circuit of Figure 1 a negative-polarity pulse is applied through capacitor C_1 to the common plate-circuit resistor R_7. Some of the pulse energy will travel through plate resistor R_4 and be dissipated largely in the low impedance of conducting triode *2*. Part of it may reach the grid of the triode *1* by way of C_3 but no action results from this since triode *1* is cut off. A second portion of the pulse energy will find its way to the grid of triode *2* by way of plate resistor R_1 and capacitor C_2. The resulting negative swing in this grid voltage causes a reduction in plate current in triode *2* and raises its plate potential slightly. This increase in plate potential drives the grid of triode *1* in the positive direction to start conduction through it. This initiates a drop in plate potential at *C*, which is transferred to *D* to reinforce the effect of the negative driving pulse. This loop feedback drive is highly cumulative and the circuit very quickly triggers over to its other stable state with triode *1* on and triode *2* off.

In a similar manner the next applied negative input pulse will return the circuit to the starting point. In practical use a reset switch may be connected, as shown, to open the bias lead. This causes triode *2* to go on (if it is not already on) and insures that the circuit is returned to its starting point. An output connection for a succeeding stage may be taken from point *A*. The input capacitor of this next stage will differentiate the output of triode *2* to give negative and positive drive pulses. Since a given stage responds only to negative pulses, there is a division by two in each binary stage.

This locking-type multivibrator possesses the essential requirements for counting purposes. First, it has a multiplicity of stable states (only two, however). Second, identical input pulses cause it to go from one stable state to the next. It also has the property of delivering output pulses which are identical or can be made identical with the input pulses. This points the way to a means of combining a group of binary stages to get any desired number of stable states.

BINARY GROUP

Figure 2 shows a group of four locking-type multivibrators connected in a binary chain. Such a series arrangement has a capacity of 16 counts. The value of the count at any time may be indicated by means of small neon lamps *N* arranged as shown. If these lamps are assigned the values 1, 2, 4, and 8 from left to right, the value of the count will be the sum of the values of the lamps that are on. Obviously, the length of a binary chain can be extended indefinitely to have as great a capacity as desired. The capacity equals 2^n, where n is the number of states.

BINARY DECADE

Since our numerical system is based on the decimal principle, the binary system is inconvenient to use. Figure 3 illustrates a binary chain of four stages with modifications that convert it to a decimal basis. This decade circuit, as it is called, has a capacity of 10 counts. The theoretical capacity of 16 is reduced to 10 by means of two feedback links. One feedback is from the left-hand triode of *MV-3* to the right-hand grid of *MV-2* and the other in a similar connection from *MV-4* to *MV-3*.

The operation of this decade can be better understood if reference is made to the chart of Figure 4 which shows the operating sequence of the four multivibrators. The top line shows the zero or starting condition with the right-hand triode of each multivibrator on. When the first input pulse is applied, *MV-1* is tripped over with its left-hand section on. The second input pulse returns *MV-1* back to the starting condition which sends a pulse ahead to trigger *MV-2*. After the third pulse is applied, the first two stages are both left with the left-hand sections on, while the last two stages have not yet been tripped. The operation this far has been according to the conventional binary-chain sequence.

The fourth input pulse produces a modified action. *MV-1* trips back to the right which causes *MV-2* to do likewise. This sends a pulse ahead to trip *MV-3*. As the left-hand section of *MV-3* goes on, a pulse is fed back to return *MV-2* to its previous condition which it held on the count of three. This feedback action is equivalent to

advancing the settings of the entire chain by two counts and is the first step in reducing the capacity from 16 to 10. In other words, two counts have been lost or eliminated. The fifth input pulse trips *MV-1* again with no action elsewhere in the circuit. A second feedback action takes place when the sixth pulse is applied. *MV-1* trips back to the right which also trips *MV-2* to the right. This trips *MV-3* also back to the right but only momentarily because *MV-4* is tripped to feed back a return pulse. This action of *MV-3* is similar to that that took place at *MV-2* two counts previously. Advancing *MV-3* in this way results in reducing theoretical capacity by 4 more counts.

By means of these two feedback steps, the maximum possible capacity of 16 counts for four double triodes has been decreased by 6 counts to a new capacity of 10. The sequence of operation for the next 4 counts follows the conventional binary pattern, and after a total of 10 counts the decade is back to its starting point.

Although the arrangement of neon indicating lamps across plate resistors, as mentioned previously, could be used to show the recorded count, a better system would be to have a single lamp to light for each count. Figure 3 shows how this may be done by means of a network of 12 resistors. A combination of three voltages from the plates of three appropriate triodes is used to produce conduction in each of the ten indicators. One of these voltages is taken from a plate-resistor midpoint on *MV-1*. This determines whether an odd or even number should be shown. The other two voltages are taken in five combinations from the other three stages.

For the indication of zero, all the right-hand triodes are on. The upper terminal of the zero lamp is connected, by way of a resistor, to the left-hand plate resistor of *MV-1*.

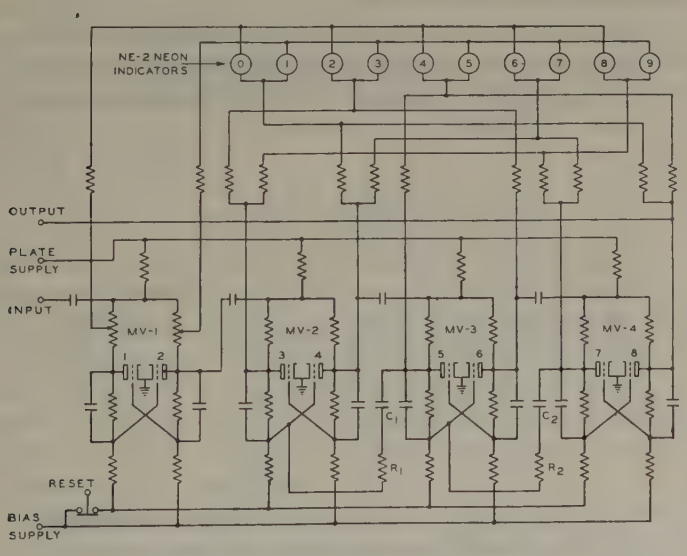

Figure 3. Binary decade circuit

This places a relatively high potential on the upper side of the lamp. The lower terminal of the zero lamp is connected by way of two separate resistors to the right-hand triodes of *MV-2* and *MV-4*. These two points are both at relatively low potential so that the resulting potential across the zero lamp is great enough to fire it and keep it on. Each lamp in turn operates on a combination of one high-value voltage and two low-value voltages.

OTHER COUNTER COMBINATIONS

Binary chains can be connected with suitable feedback links to have any integral capacity whatsoever. They also can be arranged in various compound relationships. Figure 5 shows a ring chain of multivibrators whose capacity in counts is equal to the number of multivibrators in the chain. In this combination one right-hand triode can be on while the others are off. The drive pulses are applied to all the multivibrators in parallel but only the "on" stage is receptive. As this "on" stage is tripped off, it triggers the next succeeding stage on. The count is indicated by whichever right-hand triode is on. This type of circuit is advantageous for certain applications but it is uneconomical in its use of tubes for general counting purposes.

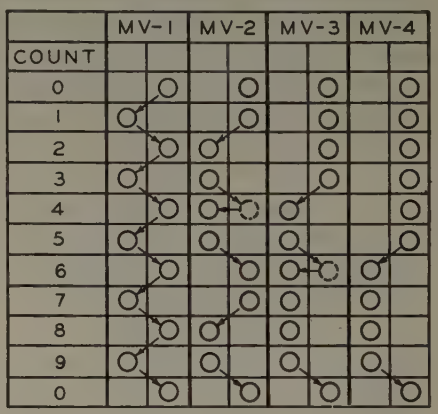

Figure 4. Binary decade operating sequence

Figure 5 also shows two examples of a two-by-five system. This scheme often has been used to get a decimal count. Six multivibrators may be arranged in a series or a parallel arrangement. In these combinations the first stage counts by two's and a ring chain counts by five's. The indication of count is given by a combination of two voltages.

Another type of ring circuit is given in Figure 6. This uses gas tubes or thyratrons. The setup or preparation principle is used here. One tube at a time is conducting, and it prepares the next tube in the ring to receive the next drive pulse. This is done by causing the bias of any given tube to be supplied partially from the cathode resistor of the preceding tube. The prepared tube thus has less bias than other off tubes and so will be the next to trip. Kick-back capacitors are connected between adjacent plates, so that when one of the gas tubes fires, it will extinguish the preceding one which had been on.

SWITCHING CIRCUITS

Practically all electronic counters require an associated switching circuit for initiating and terminating the flow of pulses to be counted. There are many circuits for performing this function; Figure 7 gives a circuit which has

proved to be very satisfactory. It consists of a gate tube, a gate opener, and a gate closer. The gate or switch tube is a pentode, and its condition is controlled by the action of the other two tubes which are of the gas type. Gating is accomplished by raising and lowering the screen-grid voltage of the gate tube.

The incoming pulses to be counted, having positive polarity in this case, are applied to the control grid of the pentode. This control grid is biased well below cutoff so that plate conduction can take place only during each pulse peak, provided that the gate is open. During the initial or standby condition the screen is held at a negative potential so that there is no output irrespective of control

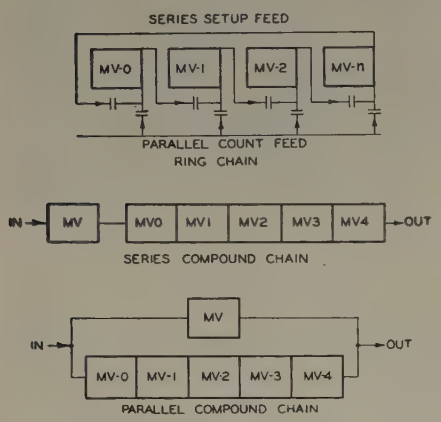

Figure 5. Binary chains

grid behavior. This condition persists as long as the gate opener *A* and gate closer *B* remain untriggered.

To start the flow of pulses through the gate, a start pulse is applied to trigger the gas tube *A*. As the gate opener fires, it suddenly raises the screen voltage of the gate pentode from the negative value up to the normal operating positive value. After this happens, each applied positive input pulse causes plate conduction which results in an amplified, negative-polarity output pulse. The gate remains open and the flow of output pulses continues.

To close the gate a stop pulse is applied to trigger the gate closer *B*. This gas tube quickly pulls the screen voltage of the gate tube back down to a negative value and the flow of output pulses ceases. Both gas tubes remain in the conducting state until the reset switch is pushed to restore the switching circuit back to its standby condition.

The wave forms of Figure 7 illustrate the performance just described. Although the input pulses are shown with a uniform occurrence rate, this obviously is not necessary. In some cases a sine-wave signal may be used on the control grid of the gate, and the output will consist of negative peaks of a clipped sine wave.

This gate or switching circuit possesses a number of features which make it most useful in many counter applications. The first of these is the lockout feature. This means that the gate will open and close only once without resetting, irrespective of further pulses applied to the gas tubes. A second feature is the interlock which prevents the gate closer from being accidentally tripped prematurely ahead of the gate opener. This sequence is assured since the lower gas tube has no plate voltage until the upper tube has been tripped.

The interlock may be further affected and given a controlled delay. This can be done by applying a portion of the gate voltage from the cathode of the opener tube to the grid of the closer tube through a delay network. With delayed interlock the start- and stop-pulse input terminals may be tied together for single-line operation. The first pulse to arrive on the line will open the gate and the next one will close it.

THE COMPLETE COUNTER

Although the essential parts of an electronic counter are the decades and switching circuit, other parts usually are included to make up a complete commercial unit. One model now available on the market has a 1-megacycle crystal-controlled oscillator, a switching circuit, six decades, and a power supply all included in a 9- by 11- by 17-inch portable case. This instrument has a capacity of one million counts and a maximum counting rate of one million per second. If it is used as a timer it will measure intervals up to one second with a resolution of one microsecond.

APPLICATION AS A STOP WATCH OR TIMER

Some of the functional details of counters having been described, applications will be considered next. Among these the application to time interval measurement has been important. Considering basic principles again, two methods of time measurement are to be noted. In one of these a continuously running timing element is used. A time interval is measured by noting the timer reading at the beginning and end of the period and taking the difference of the readings. This method is not too well suited to electronic counters because of the limited speed of response of the neon indicator lamps.

The better method of using the electronic circuit is the start-stop scheme, which is similar to using a stop watch. Electric pulses are developed to mark the beginning and

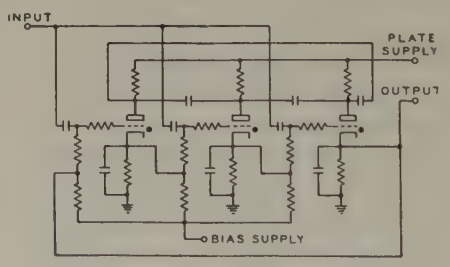

Figure 6. Ring-of-three circuit

end of the interval to be measured, and these are fed in to trigger the switching circuit. If the counter decades are initially set to zero and the cycles of an accurate oscillator are counted while the gate is open, the indicated result can be given as a decimal fraction of a second. If a stable 1-megacycle oscillator is used the measurement will be correct to ± 1.0 microsecond.

There are many cases where measurements of this category can be made best with an electronic counter. For example, the performance of electromechanical devices

can be studied. The closing or opening time of a relay can be measured easily.

One special case of electronic time measurement was in the field of nucleonics. The time interval to be measured was of the order of a few microseconds and this interval occurred only a few times per hour in a random pattern. To meet this problem a 6-stage binary chain was used and driven from a 4-megacycle oscillator. This gave a capacity of 16 microseconds with the accuracy of ±0.25 microsecond.

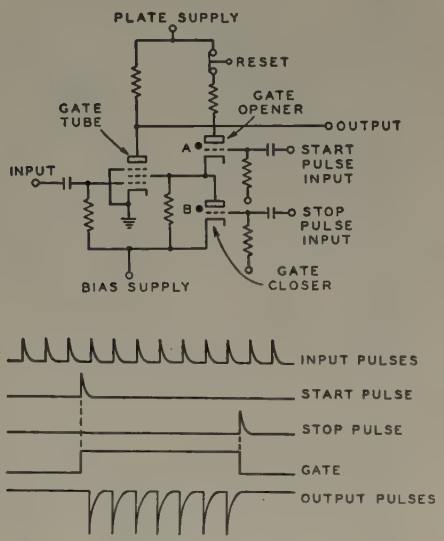

Figure 7. Gas tube switching circuit, and wave forms for switching circuit

Because of the long intervals between measurements, and since observations were made over periods of several days at a time, an automatic recording device was included with the counter. The record was made as a series of dots produced on teledeltos facsimile recording paper. After each operation, the paper was advanced and the electronic circuit returned to standby. A particular feature was that of automatic reset after 16 microseconds for cases where the start-pulse was not immediately followed by a stop-pulse.

FURTHER APPLICATIONS

Electronic counters have been used for several years in the measurement of projectile velocity. This is essentially a time interval measurement. The magnetized projectile is fired through two pickup coils, which are spaced a known distance apart. Passage through the first coil trips the gate opener and passage through the second coil trips the gate closer. The ratio of the distance to the measured time is the average speed.

Assuming that a counter having a 1-microsecond resolution is used, it is interesting to note that the accuracy of time measurement is comparable to the accuracy of linear measurement along the firing range. For example, if the projectile velocity is 3,000 feet per second it goes only 1/28 inch in a microsecond. A microsecond is very short indeed. Light travels only 980 feet in a microsecond.

Another application is in the measurement of frequency. In this case two counters are used. The first one is used as a timer to mark off a 1-second interval. The second counter counts the cycles of the unknown source for the 1-second interval, and its indication is the frequency expressed in cycles per second. The accuracy is ±1 cycle. Frequencies too high for a counter to handle may be reduced by heterodyne action.

In addition to these applications already mentioned, electronic counters find many uses in high-speed counting of objects. One of these is the pill counter. The circuit can be set to count off a predetermined number and repeat. This may be accomplished by presetting the decades to the compliment of the desired number and letting them run out, or a tripping pulse may be produced by coincidence of voltages selected from appropriate circuit points.

HIGH-SPEED OPERATION OF COUNTERS

Because of the demand, considerable attention has been given to finding means of increasing counting speeds. In general, the same basic difficulties are encountered as those presented in wide-band video-frequency amplifier design.

As a first step in analyzing the problem, the circuit for one section or one-half of a binary stage may be reduced to the equivalent circuit of Figure 8. In this diagram C_T represents the equivalent total plate-to-ground capacity in the circuit. This includes not only the coupling and output drive capacity but also the stray and internal tube capacity. R_p is the dynamic internal plate-to-cathode resistance of the tube. Since electron transit time is not the first speed limitation encountered, the dynamic action of the tube may be represented approximately by the switch K. The condition for cutoff is with K open, and for conduction with K closed.

For high-speed performance, it is necessary that the swings in potential of point E, as the switch is operated, take place as rapidly as possible. For given values of R_L and R_p the speed of response is limited by the size of C_T. When the switch is opened, C_T charges through R_L, and when the switch is closed, it discharges through R_p. Obviously all three of these circuit elements should be as small as possible if the highest speed of operation is desired.

Although other considerations are involved, the value of R_L usually can be made as low as R_p. The ultimate speed of this circuit is then dependent on R_p and C_T, and is inversely proportional to their product. This condition may be expressed as

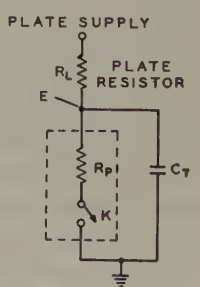

Figure 8. Equivalent circuit for high speed considerations

$$S = \frac{K}{R_p C_T} \qquad (1)$$

where S is the speed in some chosen unit, K is a units con-

version factor, and R_p and C_T are as indicated in the diagram in Figure 8.

Although C_T includes external as well as internal capacitance, it still remains that the maximum obtainable speed depends primarily on characteristics of the tube. The foregoing expression may be modified somewhat to give a better factor of merit. Since the value of R_p depends mostly on how much current the tube will pass without

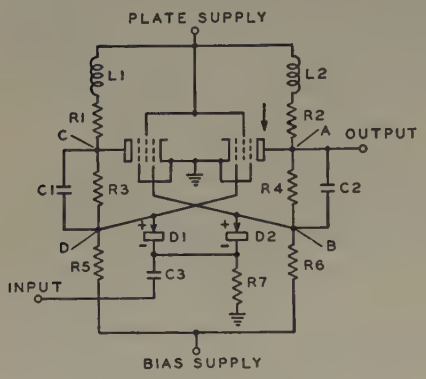

Figure 9. High-speed binary stage

injury, and this current is inversely proportional to R_p for a given voltage, the formula may be rewritten as

$$S=\frac{KI_T}{C_T} \qquad (2)$$

If I_T (the tube current) is expressed in milliamperes, K is equal to unity, and C_T is expressed in micromicrofarads, then S is the factor of merit in milliamperes per micromicrofarad. In other words, this formula states that a tube suitable for high-speed operation should be able to handle as much current as possible with as low an output capacitance as possible, or more strictly speaking, the ratio of current to capacitance should be high. It is interesting to note that equation 2 obtained by simple deductions is also the equation for the maximum possible rate of voltage buildup for the conditions indicated.

Although this expression is the primary criterion to use in high-speed design, there are other factors to be considered. The tube also should have a high value of grid-to-plate mutual transconductance so that changes in plate voltage will produce sufficient changes in the opposite grid voltage to insure switchlike operation. Although R_L would be made comparable to R_p in value, too low a plate resistor would develop too low a plate voltage swing for good utilization. It should be remembered also that C_T includes all the plate-circuit output capacity and not that of the tube alone.

In addition to selecting the best tube, increased gains in speed can be realized by use of certain circuit features. Two of these are shown in Figure 9. The effect of the plate-circuit capacitance, as discussed, can be partly compensated by the use of plate-circuit inductances. The advantage gained by their use is similar to, but not as great as, that obtained in wide-band amplifiers.

The use of crystal diodes *D1* and *D2* in the drive circuit has led to greater stability and higher operating speeds than were previously attainable, since they offer several advantages. In the first place, their use allows the driving or trigger pulses to be applied directly to the grids through low-impedance paths. Because of the back-to-back arrangement of the diodes, this is accomplished without producing grid-to-grid coupling which would be degenerative.

A second advantage occurs on account of the manner in which the drive pulses automatically are distributed alternately to the two grids. This comes about as a result of the manner in which the diodes are biased through resistor R_7. If the right hand pentode is on, its grid terminal *D* will be at approximately ground potential. This will cause diode *D1* to have the same d-c potential of ground to exist on both sides of it. Diode *D2* will have its upper terminal at a much lower value of potential since it is connected to terminal *B* of the grid which is at cutoff potential. When a negative-polarity drive pulse arrives by way of input capacitor *C3*, it will be transmitted through *D1* but not through *D2* because of these potentials. As a result the initial part of the drive pulse will be applied only to the more positive grid and none of its energy will be wasted in driving the negative grid in the wrong direction. Because of these things, the binary stage of Figure 9 is very easy to drive even at speeds of several megacycles. As may be suspected, miniature pentodes have been found to be practical at such speeds. The use of such binary stages as these has made possible the development of a successful 10-megacycle decade.

CONCLUSION

All through this discussion on counters no reference has been made to the currently active field of electronic computers. Even though such a discourse belongs outside the scope of this article, a few closing comments may be of interest. The counter decade which has been explained in some detail can be regarded as one element that could be used for many purposes in a large computer. Its function in this role would be comparable to that of a number wheel in an adding or computing machine. Here again, the tremendous speed of the electronic circuit more than makes up for its complication. For a 10-position number wheel to match electronic speed, it would have to move at upwards of 100 million rpm. This illustrates the basic advantage of electron tubes in computing devices.

Although the 4-tube counter decade has been available only a few years, its rapidly increasing number of applications is proof of its importance. In most cases its function is that of a test or measuring device. In view of the increasing efforts being made in all branches of science, it appears that there should be a good future for electronic digital counters.

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Antennas for Radiation Measurements

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RADIATION from diathermy, electronic heating, and other industrial devices is now subject to federal regulation. There is no commercial equipment available that is suitable for measuring electromagnetic fields at frequencies above 400 megacycles per second. The present procedure is to use the receiver-signal generator substitution method. This requires the use of a pickup device of known characteristics.

The ideal antenna for this purpose would be one that is small, of fixed dimensions, omnidirectional, sensitive, of constant effective length, and of constant self impedance. It so happens that several of these factors are mutually antithetic. For example, smaller antennas are, in general, less sensitive than larger ones, and the more sensitive antennas are highly directional. Also, for a fixed length the self-impedance is a function of frequency. A compromise, therefore, is necessary in order to obtain a useful antenna, or set of antennas, to cover a specific range of frequencies. Any compromise, however, must be made in such a way that the electrical characteristics of the antennas are known or obtainable for each frequency to be used.

Early treatment of electromagnetic wave generation was based on the radiation from an elementary dipole of infinitesimal length. The treatment was next extended to longer antennas of infinitely small radii and with sinusoidal current distribution along the antenna. Later investigators have obtained working equations for practical antennas by analysis based on certain simple geometric forms such as cones, spheres, and cylinders.

Decreasing the ratio of the length to the radius of a half-wave or a quarter-wave antenna lowers the characteristic impedance and also broadens the band of frequencies over which it may be used without changing its length. Both of these effects are useful in designing an antenna for general radiation measurements.

To obtain sufficient sensitivity it is usually necessary to employ some form of reflector or horn. Although any one of many different types could be used for specific measurement purposes, there are relatively few that are suitable for general field measurements and which can be duplicated in the average small machine shop. The corner reflector and the horn of Figure 1 meet these requirements.

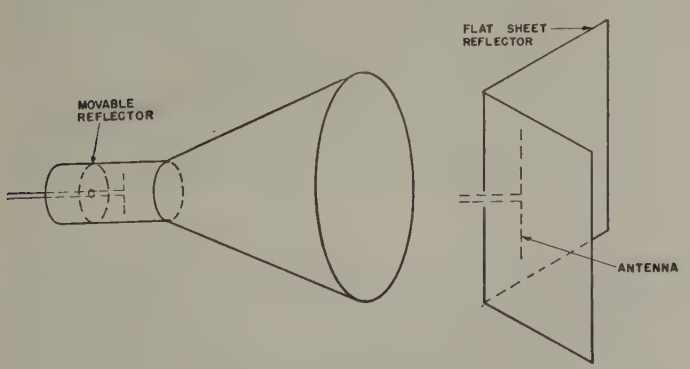

Figure 1. Dipole antenna with conical horn and corner reflector

For the measurement of weak fields, it is desirable to work in terms of field intensity (in microvolts per meter) rather than power, because of the convenience of using signal-generator microvolts and antenna factors. The

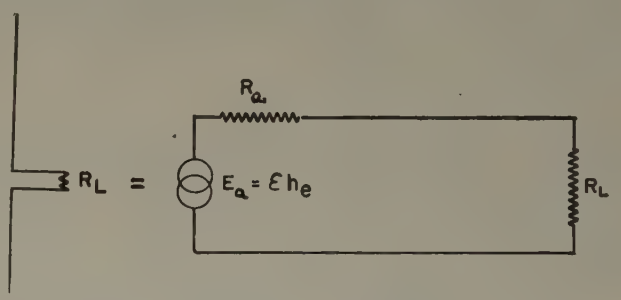

Figure 2. Equivalent circuit of a half-wave dipole

relationship between power and field strength for a matched antenna is given by

$$P_L = \frac{(\mathcal{E} h_e)^2}{4R_a} \text{ watts}$$

where P_L is the power delivered to the load, $\mathcal{E}$ is the field strength in volts per meter, h_e is the effective length in meters, and R_a is the radiation resistance of the antenna.

The effective cross section is related to the effective length by the expression

$$A = \frac{h_e^2 R_C}{4R_a} \text{ square meters}$$

where R_C is the impedance of free space.

The gain of any antenna having an effective cross section, A is given by the expression

$$G = 4\pi A/\lambda^2$$

where λ is the wave length in meters. Although the approximate effective cross section or the approximate gain of the antenna may be determined from design data, it is best to make an actual measurement of these factors where the highest possible accuracy is required. This may be done by comparing it with a standard antenna, such as a half-wave dipole, under properly controlled conditions.

Figure 2 shows an equivalent circuit of a half-wave dipole. For maximum power transfer, R_a and R_L, the resistance of the load connected to the antenna, are matched.

Digest of paper **48-286**, "Ultrahigh-Frequency Antenna Considerations for Radiation Measurements," recommended by the AIEE electric heating committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

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Carrier Telemetering Load Control

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THE POWER SYSTEMS in the Southwest were banded together during the war to provide adequate capacity for supplying energy to large war industries in that area. To insure delivery of power and assist the dispatchers, the area was equipped with extensive carrier communication, telemetering, and load-control facilities. Since the war it has become increasingly necessary for each system to carry its own loads. Effective scheduling of generation could be obtained only by giving the system load dispatcher the proper load information at strategic points on the system.

Load information on the Oklahoma Gas and Electric Company's eight interconnections with other power companies, an intrasystem tie line, and four of the largest generating plants is telemetered into the load dispatcher's office in Oklahoma City. In order to provide smooth and efficient operation of this system, the following features for a telemetering and load-control system were deemed necessary: load information on generating stations and tie lines; provision for totalizing net load on all interconnections; load control based on tie-line bias or system frequency; communication facilities between load dispatcher and generation stations; provision for adding telemetered quantities to allow for power system expansion.

Figure 1 shows a simplified diagram of the recorders and control. The retransmitted output of the tie-line recorders is fed into the net interchange recorder. Another set of retransmitters on the tie-line recorders is fed into the tie-line bias-recording controller. The system frequency recorder contains the controls for bias settings. The generating plant recorders *A*, *B*, *C*, and *D* are shown also. The manually operated potentiometer *E* simulates the output of small nontelemetered generating plants.

The master load-frequency controller is responsive to the tie-line bias controller and the system frequency meter and originates the load-control impulses. The Horseshoe Lake generating plant was selected as the regulating station to control the tie lines, and receives "raise" and "lower" impulses over one of the carrier channels.

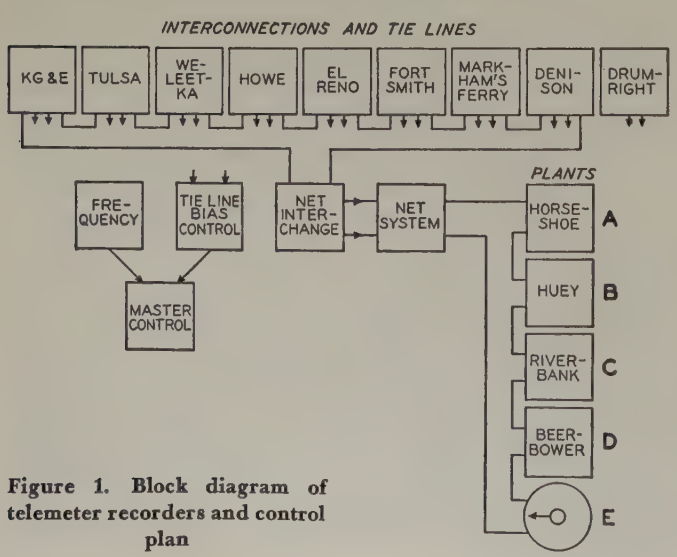

Figure 1. Block diagram of telemeter recorders and control plan

A survey of the use of the 50–150-kc carrier band in the area showed that this frequency range was well utilized, and left insufficient channels for the telemetering system contemplated. This fact was confirmed by actual monitoring tests. In view of this condition, it was decided to go to higher frequencies with the majority of the telemetering signals between 150 and 250 kc. The length of the carrier channels, the higher frequencies used, and other factors increasing attenuation required the use of two repeat stations to hold a favorable signal-to-noise ratio with standard carrier transmitters and receivers.

In order to utilize each carrier channel as much as possible, tone modulation of the carrier signal was employed so that several telemetered quantities could be transmitted over a single carrier channel. From Fort Smith and Howe, tone-modulated signals are transmitted to Riverbank where they energize two tone receivers. Output relays on these units in turn key two tone transmitters (of the same audio frequencies) to modulate another transmitter. This method of repeating has the advantage of eliminating all noise in the received signal.

From most of the other outlying stations, a single quantity is transmitted by tone modulation. All of the signals are received at Horseshoe Lake on a total of five receivers. The receiver outputs are connected in parallel in two groups and together with one tone for local generation modulate two transmitters, thus repeating all the telemetering signals into Oklahoma City. The received impulses are routed to their respective recorders, and are totalized to originate "raise" and "lower" impulses to be transmitted back to generators at Horseshoe Lake on a different carrier frequency with two tones.

This carrier telemetering and load-control system has effected more efficient and economical operation of the power system. A continuous record of the net interchange between systems has been kept, as well as the load on each large plant and the total load of the system.

Provision has been made to allow for future growth when it will be necessary to add more telemetered quantities and load-control channels without making the existing equipment obsolete.

Digest of paper **48-296**, "System Operation Improved With Carrier Telemetering Load Control," recommended by the AIEE carrier current committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Transmission Line Design and Performance Based on Direct Lightning Strokes

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FELLOW AIEE

J. M. CLAYTON

A method for estimating the lightning performance of transmission lines is presented in this article. It is based on the stroke current probability data and takes into account all the line parameters believed to affect the performance materially. The curves cover the complete range of transmission line designs.

IT IS WELL KNOWN that the insulation requirements of transmission lines are determined by lightning and switching transients rather than by the normal frequency voltage. For lines up to the highest voltages now in use, lightning is usually a principal factor. Consequently, a method for predetermining the design requirements to provide a desired immunity against lightning tripouts is essential. A great deal of thought and effort has been devoted to developing such a method. Much painstaking work has been done in the collection of information regarding lightning currents to provide a fundamental basis for the estimates.

In this article there is presented a method which has been in increasing use for a number of years for specific design calculations, and which is based on the stroke current probability data. This method now is extended into a complete set of estimating curves covering the full range of insulation levels, span lengths, and tower footings encountered on transmission lines. This is essentially a refinement and extension of the general curves given by Monteith.[1] However, it takes into account the improved knowledge of the lightning phenomenon obtained through field research and confirmed by actual line performance since then.

The previous curves were based on the stroke voltage which was considered to be constant irrespective of what line structure was hit. This required the assumption and use of a stroke surge impedance. In the present curves the stroke current is taken to be independent of the line structure hit so that the stroke surge impedance concept is not required and the method is tied more directly to measured currents. The latter representation is believed to be more nearly correct for reasons that will be outlined. In general, the changes from the previous curves are not large, particularly for the lower tower footings of 20 ohms or less. There are some significant changes for higher tower footings encountered in certain territories and for the shorter spans used for lower-voltage wood-pole lines, such as 33 kv. These differences will be enumerated. The new general curves also include shorter span lengths than were included previously.

The new method of approach involving the treatment of the lightning stroke current as a constant fixed current rather than as a constant voltage back of a stroke surge impedance was introduced by Doctor G. D. McCann and Doctor C. F. Wagner[2,3] several years ago, and the quite extensive field data accummulated to that time indicated that this was a better representation and gave results which more strictly agreed with experience. The new method brought to bear on the problem the valuable field data which had been collected on stroke current and the accompanying theoretical approach enabled these data to be interpreted for comparative purposes on all forms of line design.

In all methods of estimating lightning performance the mechanism considered is as follows. The direct stroke theory being well established, it is known that in a region of average storm intensity of 30 storm days per year, the line will be hit by approximately 100 direct strokes per 100 miles per year on the average. Thus a shield wire must be used to receive these direct strokes and thereby shield the remaining conductors. This may be a ground wire which provides a suitable shielding angle or a top phase conductor equipped with protector tubes. The lightning current then is expected to take the path along the shield wire, down the tower, and through the tower-footing resistance to ground.

The entire tower top and connected ground wire rise to a high voltage principally because of the *IR* drop in the tower footing. Neglecting coupling between the ground and phase wires, all this voltage would be impressed on the line insulation. Coupling elevates the phase wire voltages, so that the actual voltage impressed on the insulation is the tower-top voltage to ground times (one minus coupling).

It is evident that the tower lightning current required to cause flashover can be determined for any given insulation level, tower footing resistance, and coupling factor. The relation is

$$\text{Tower current to cause flashover} = \frac{\text{insulation flashover voltage}}{\text{Tower footing resistance} \times (\text{one minus coupling})}$$

The probability of line flashover is the same as the probability of tower currents equal to or greater than this value.

The problem is not as simple as outlined up to this point for a number of reasons. The insulation flashover voltage must be given for the wave shape of voltage to which it is exposed, which depends in turn on the wave shape of the stroke current and such factors as span length, tower foot-

Essential substance of paper 49-111, "Transmission Line Design and Performance Based on Direct Lightning Strokes," recommended by the AIEE transmission and distribution committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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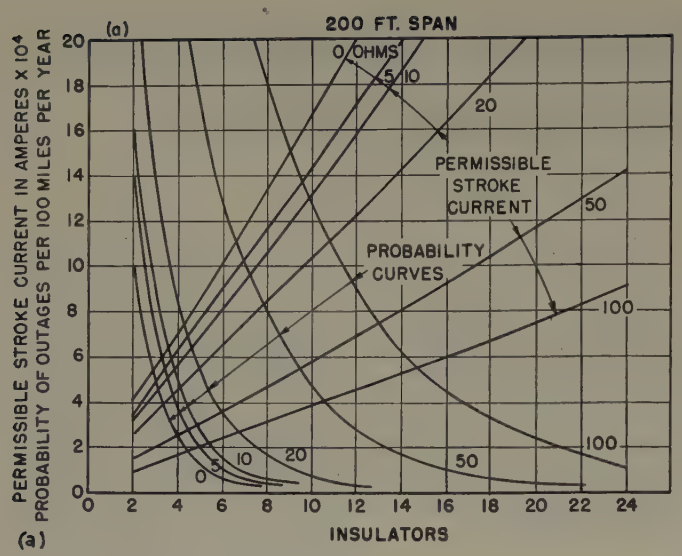
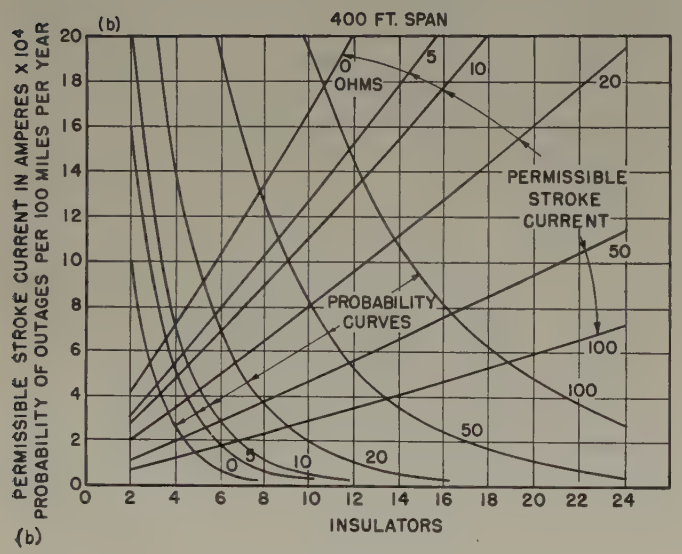
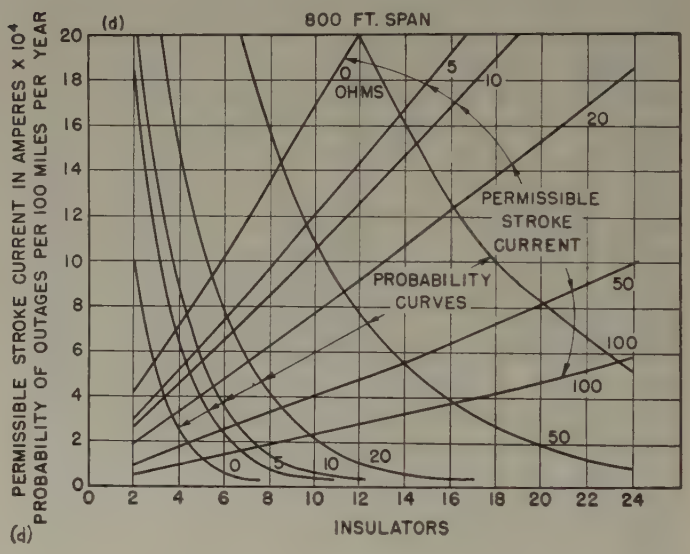


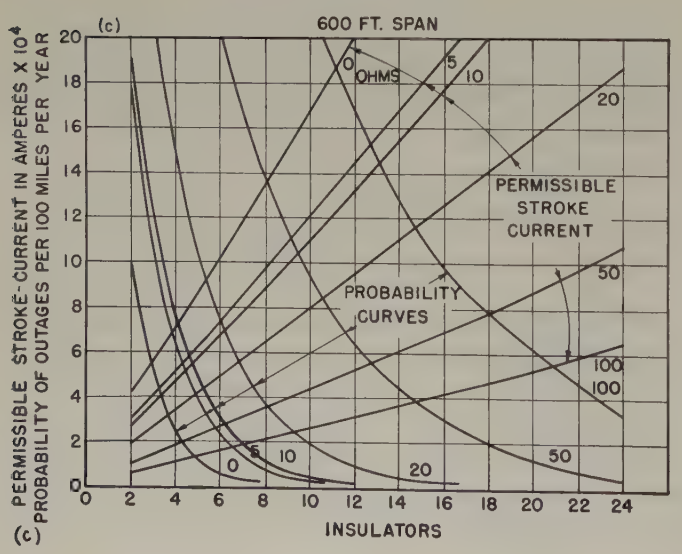
ing, and so forth. Tower inductance is important as well as tower footing resistance when the latter is low (under 20 ohms). The coupling varies with corona which is a function of the voltage, spacings, and so forth. Finally, while the most extensive lightning data available are tower crest current data, the tower currents resulting from given stroke currents vary with span length and to some extent with tower-footing resistance. Hence direct experimental tower current probability data can be used only for lines having the same order of span length and footing resistance as those on which the data were taken. For other lines some means of correction is necessary.

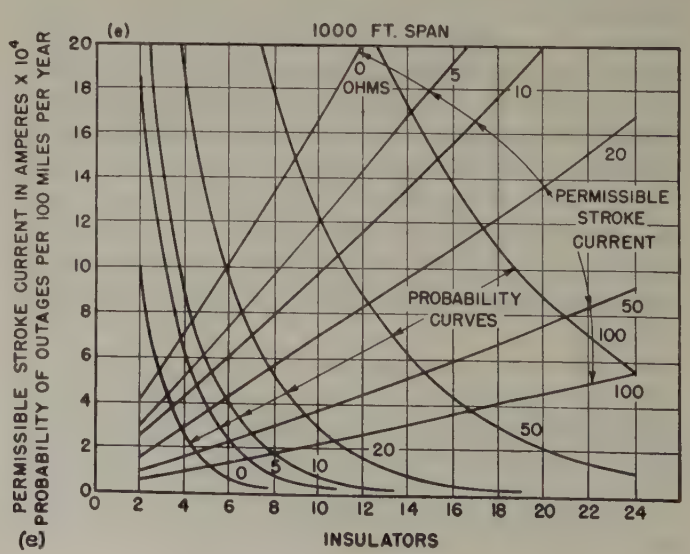
Figure 1. Curves for estimating line insulation and performance, based on 10-inch $5^3/_4$-inch-spaced suspension insulators, or equivalent, and an isoceraunic level of 30 storm days per year

The numerals on curves (a) to (h) indicate tower-footing resistance, (i) and (j) length of span



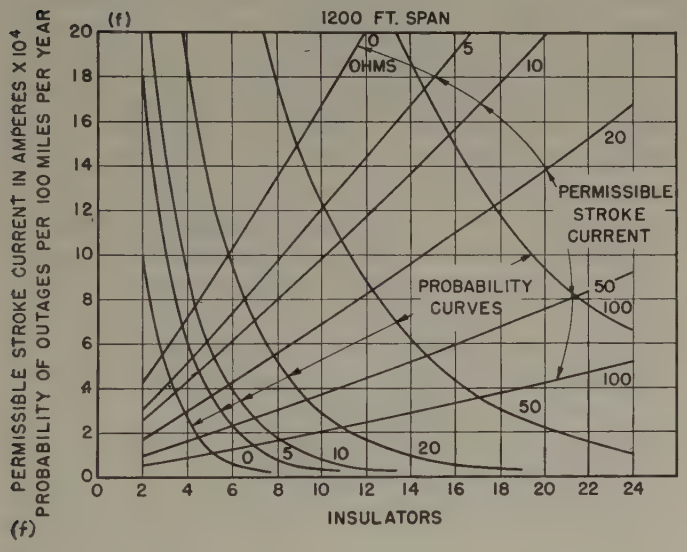


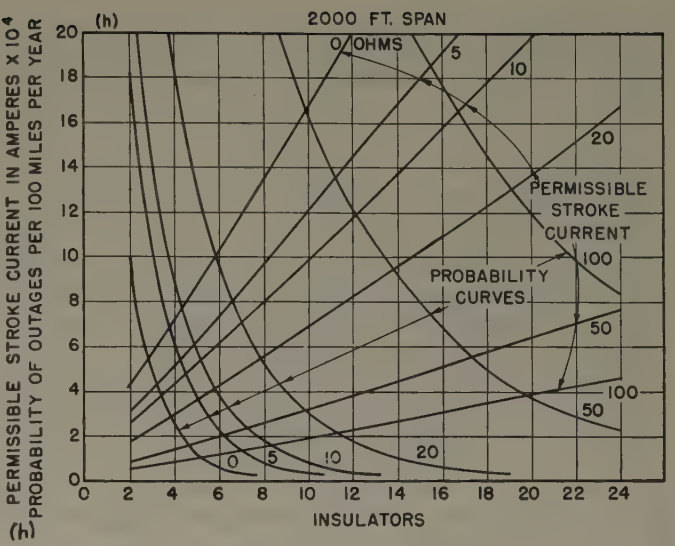


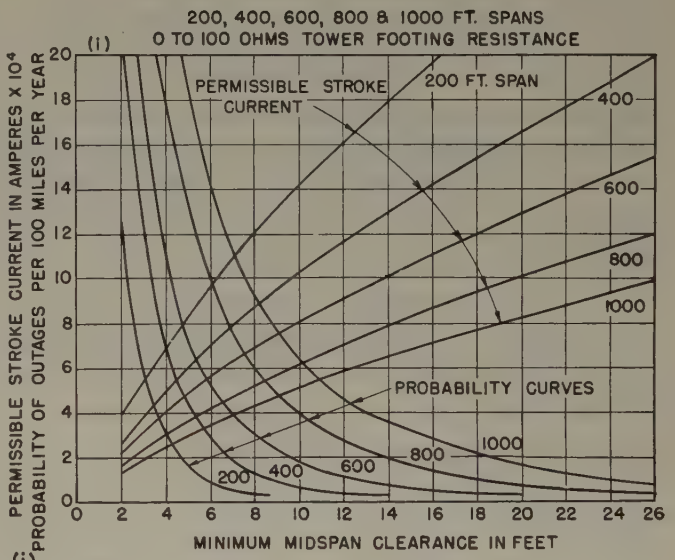


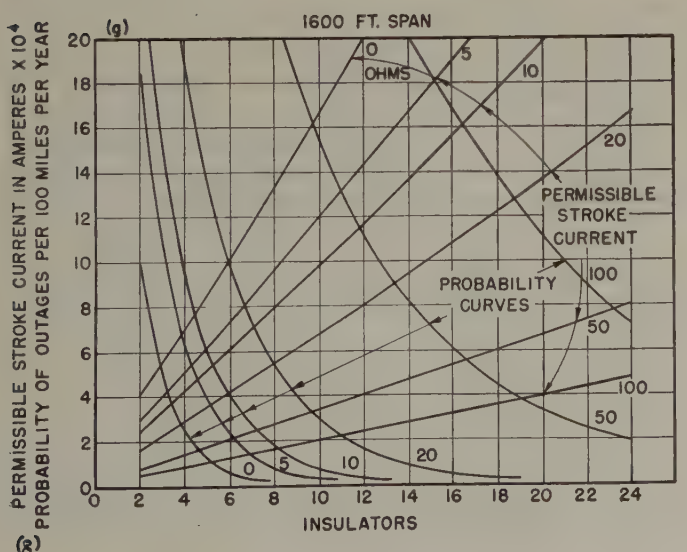
There is also the possibility of midspan flashover. The considerations are similar to those for tower flashover. The stroke current must be carried away by the ground wire, and flashover will occur if the resulting voltage exceeds the air insulation strength from ground wire to phase conductors. On many lines midspan clearances required for mechanical reasons are such as to result in a negligible number of midspan flashovers, and for this reason, certain estimating methods consider tower flashovers only. However, for a general method intended to cover all cases, midspan flashovers must be included for in some cases they may be appreciable. It is the different treatment of these practical matters that has given rise to several distinct estimating methods.[4,5]

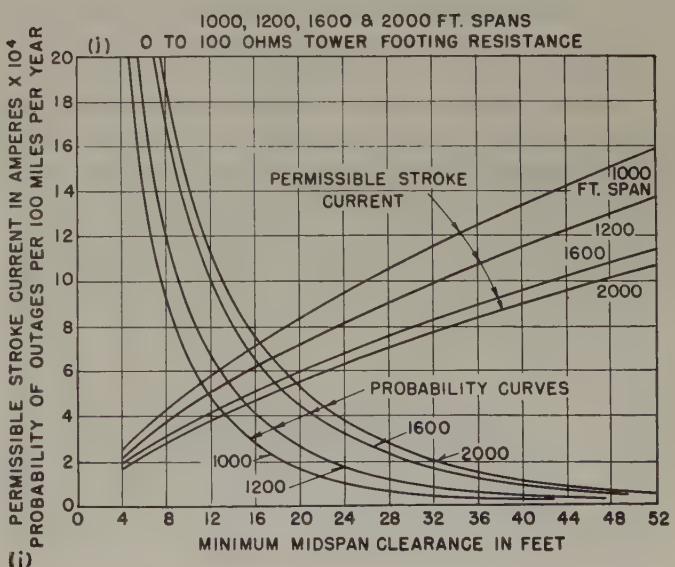
The authors recognize that the use of tower current data is the most direct and accurate approach to performance calculations of lines having about the same span length and midspan clearance as those on which the data were measured. However to provide a general analysis applicable to the complete range of designs used in transmission practice,











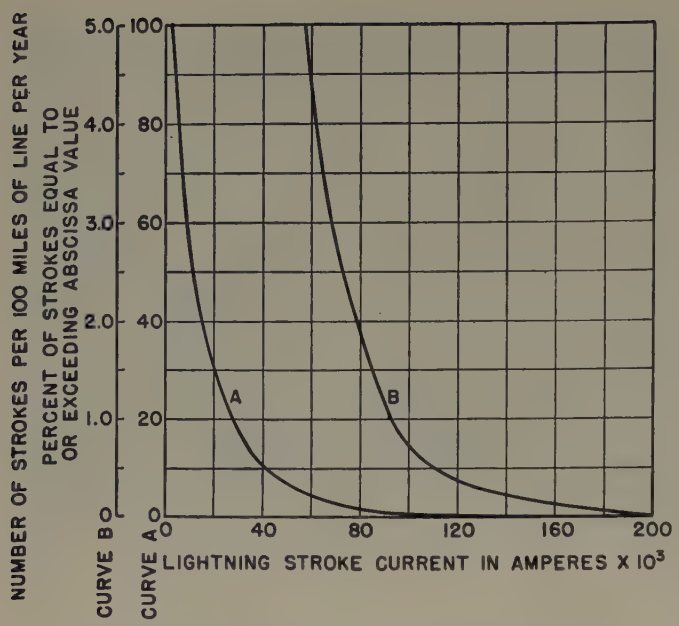

NUMBER OF STROKES PER 100 MILES OF LINE PER YEAR
PERCENT OF STROKES EQUAL TO OR EXCEEDING ABSCISSA VALUE
CURVE B
CURVE A
A
B
LIGHTNING STROKE CURRENT IN AMPERES X 10³

Figure 2. Lightning stroke current probability curve

Strokes per 100 miles of line per year for isoceraunic level of 30

a more fundamental approach is necessary. This method is based on the stroke current, tower currents then being calculated for each different design. The stroke current is treated as independent of the terminating impedance which it strikes.

GENERAL CURVES

It is evident from the foregoing discussion that the voltage to which the line insulation is subjected depends on the following factors:

1. Stroke current magnitude and wave shape.
2. Tower footing resistance and tower inductance.
3. Span length.
4. Line configuration including conductor spacings, height above ground, and so forth.

Using a typical line configuration and tower inductance and a 2×40-microsecond current wave, a general study has been made to determine the resulting voltages across the insulation at the tower and at midspan. The basis for the assumed parameters will be discussed later. This system was set up on the Anacom[6] (electric analog computer). The span length was varied from 200 to 2,000 feet and tower footing resistance from 5 to 100 ohms. This was done both for strokes entering at midspan and at tower. From the resulting potentials and wave shapes and the use of coupling factors taking into account corona, the stroke current required to cause flashover in each case was determined. These stroke currents are plotted in the general curves, Figure 1.

The probability of outage for a given case is simply the probability of stroke current in excess of that required to cause flashover. Figure 2 shows the stroke current probability curve used. The outage probabilities also are plotted in the general curves, Figure 1.

It will be noted that there are eight sets of probability curves, *a* to *h*, giving outages for strokes to the tower for span lengths from 200 to 2,000 feet. Each set covers one span length giving the probability of outage as a function of number of insulators and the tower footing resistance for that particular span length. Each set of curves also gives the permissible stroke current as a function of the number of insulators and tower footing resistance. If more accurate stroke current probability data are available for the region being considered, these curves may be used.

Outage probabilities for midspan strokes are given in curves, *i* and *j*, as a function of midspan clearance and span length only. This probability is substantially independent of tower footing resistance. For short spans the midspan flashovers would be slightly less than shown for any tower footings less than 100 ohms. However, for short spans the midspan flashovers shown are so low for practical spacings that this small reduction is unimportant.

Strokes to the line are assumed to be uniformly distributed along the line. It is furthur assumed that strokes within a quarter-span length of the tower act as though at the tower, while strokes within a quarter-span of the midspan act essentially like midspan strokes. Thus half the strokes are treated as strokes to tower and half are treated as strokes to midspan. The probability curves, however, give the performance on the basis that all strokes are to tower, or all to midspan respectively. Thus it is necessary to average the two outage probabilities obtained from the tower and midspan curves respectively rather than add them. For a co-ordinated line having equal probability of flashovers at the tower or at midspan, either curve would give the complete outages for the entire line per hundred miles per year.

The probability curves are based on an isoceraunic level of 30, which denotes an average of 30 storm days per year. For other levels it is assumed that the outages will vary in direct proportion. An annual isoceraunic level map for the United States is given in Figure 3.

The curves for estimating outages due to strokes to tower are based on a coupling factor corresponding to a 30-foot separation. For lower or higher separations the number of insulators should be corrected to allow for the corresponding change in coupling factor, the corrections being given in Figure 4. This correction is relatively unimportant for

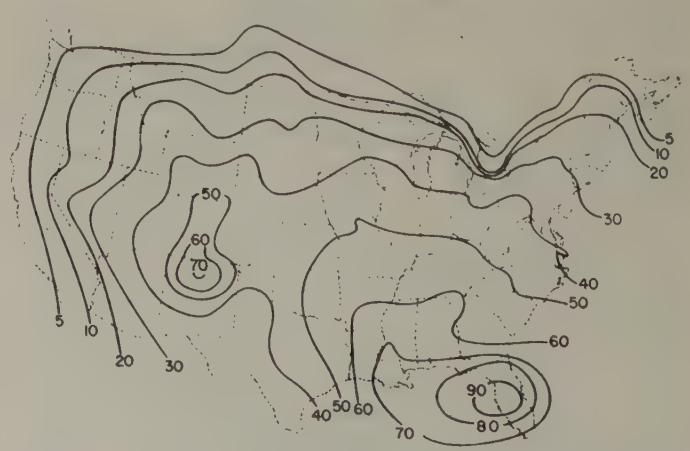


Figure 3. Annual isoceraunic map showing the number of thunderstorm days per year

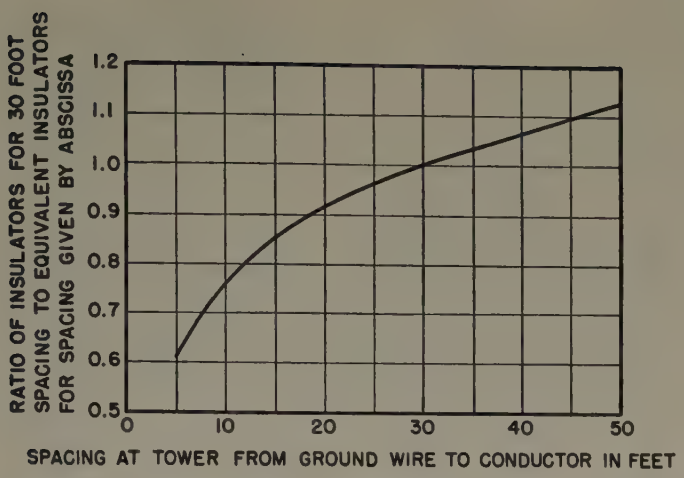


Figure 4. Correction factors for spacing at tower from ground wire to conductor

lines in the neighborhood of 132 kv but becomes more important for the lower-voltage lines such as 33 kv.

On some lines the midspan clearance may be so high that even midspan strokes will cause flashover at the tower rather than at midspan. This can be determined by finding the permissible stroke current to tower and to midspan. If the latter is more than twice the former, strokes to midspan can cause flashover at towers. In this case the outage probability for the line is the average of that corresponding to the permissible stroke current to tower and that corresponding to twice this stroke current. The resulting probability curve is given in Figure 5.

The general probability curves of tower outages have been plotted in terms of the number of $5^3/_4$-inch spaced insulators. Where other insulating media appear, they must be converted to equivalent insulators. The curves of Figure 6 provide a ready conversion from air or wood to equivalent number of insulators for estimating when more accurate data are not available. They are based on 100 kv per foot for wood and on the two microsecond time lag flashover values on $1^1/_2 \times 40$-microsecond waves for air and for porcelain insulators. This wave shape is most representative of the tower-top potentials encountered.

The probability curves are based on all flashovers causing outages. All flashovers do not result in outages[3] depending on the line insulation characteristics and other factors. For estimating purposes it may be assumed about 85 per cent of all flashovers cause outages on steel tower lines; this factor may be reduced to 50 per cent for lines over 200 miles in length. For wood-pole lines 35 to 50 per cent of flashovers usually results in outages.

Application of Curves. The use of the curves of Figure 1 in estimating the lightning performance of transmission lines will be illustrated by a few examples. The curves may be used for estimating the lightning performance of existing lines with various considered modifications, or they may be used for estimating the insulation and midspan clearance required to obtain a desired lightning performance in the design of new lines. Because of the probabilities and assumptions involved, the results should not be taken as rigorous. The chief value of the general curves lies in the facility provided for considering alternative designs on a comparative basis. A check of the estimating curves against a large amount of actual line experience does indicate quite good agreement.

Example I. A 220-kv steel-tower line, shielded by an overhead ground wire, located in a territory where the isoceraunic level is 50 has ten $5^3/_4$-inch spaced suspension insulators per string. The average span is 1,000 feet and the midspan clearance 24 feet. The tower footing resistances are 10 ohms for 20 per cent of the towers and 20 ohms for the remaining 80 per cent. What is the outage probability for this line?

From the probability curves, Figure 1*e*, for 1,000-foot spans, the outage probability corresponding to 10 insulators and 10 ohms tower footing resistance is 0.8 outage per 100 miles per year. For 10 insulators and 20 ohms tower footing resistance the outage probability is 3.0. The outage probability for strokes to tower along the entire line is $(0.20 \times 0.8) + (0.80 \times 3.0) = 2.56$ outages per 100 miles per year. The permissible stroke currents, Figure 1*e*, to tower are 98,000 and 68,000 amperes for 10 ohms and 20 ohms tower footing resistances respectively.

From Figure 1*i* the outage probability is 1.0 outages per 100 miles per year for 1,000-foot spans with a midspan clearance of 24 feet. The permissible stroke current is 94,000 amperes.

The outage probability for strokes to tower and midspan is 1.78 outages per 100 miles per year for an isoceraunic level of 30; this is the average, $(2.56+1.0)/2$, of tower and midspan outage probabilities.

The outage probability for an isoceraunic level of 50 is

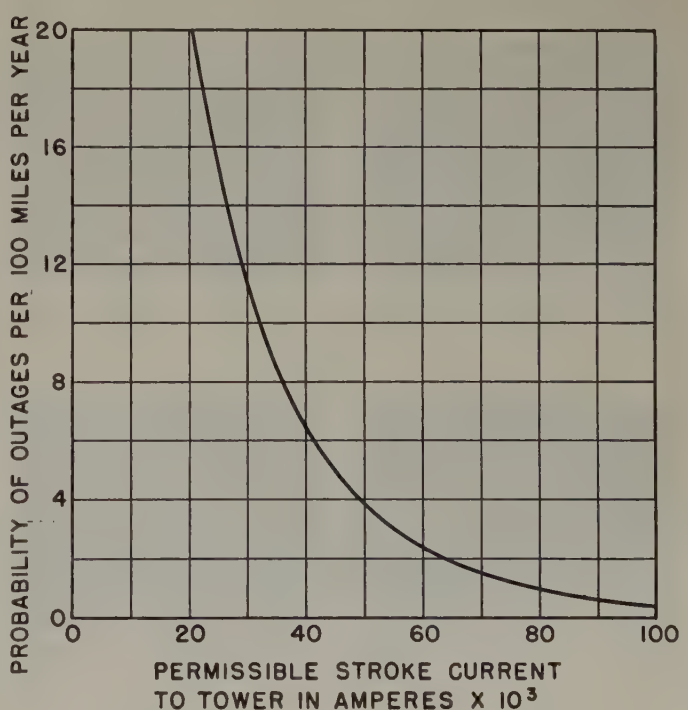


Figure 5. Curve for determining the outage probability if the permissible stroke current to midspan is more than twice the permissible stroke current to tower

50/30×1.78=2.96 outages per 100 miles per year. This is the performance expected of this transmission line.

Example II. A 33-kv wood-pole line, shielded by ground wire, located in a territory where the isoceraunic level is 30 has two $5^3/_4$-inch spaced suspension insulators per string. The minimum flashover path for any phase conductor is the porcelain plus 4 feet of wood. The average span is 200 feet and the midspan clearance 8 feet. The tower footing resistance is 50 ohms for all poles. The distance between ground wire and bottom phase conductor at the tower is 10 feet. What is the outage probability for this line?

From Figure 6, four feet of wood is equivalent to 2.6 insulators. The equivalent insulation of different insulating media may be added for estimating purposes. Thus the equivalent insulation is 4.6 insulators. Since the spacing from ground wire to conductor is considerably less than 30 feet, a correction is needed to compensate for the increased coupling. From Figure 4, the correction factor for a 10-foot spacing is 0.75. The effective insulation becomes 4.6/0.75=6.15 insulators.

From Figure 1*a*, the outage probability for strokes to tower for 6.15 insulators and 50 ohms tower footing resistance is 12.6 outages per 100 miles per year; the permissible stroke current is 36,000 amperes.

From Figure 1*i* the outage probability for strokes to midspan for a 200-foot span with an 8-foot midspan clearance is 0.3 outages per 100 miles per year; the permissible stroke current is 120,000 amperes.

Since the permissible stroke current to midspan is more than twice the permissible stroke current to tower, strokes to midspan may cause flashovers and consequently outages at the tower. For this case, the outage probability is determined from Figure 5. The outage probability for a permissible stroke current to tower of 36,000 amperes is 8.0 outages per 100 miles per year. This is the outage probability assuming all lightning flashovers result in sustained power follow and trip-out. Since part of the insulating medium is wood, approximately 50 per cent of the flashovers will result in outages. Thus the outage probability is 0.50×8.0=4.0 outages per 100 miles per year for this line.

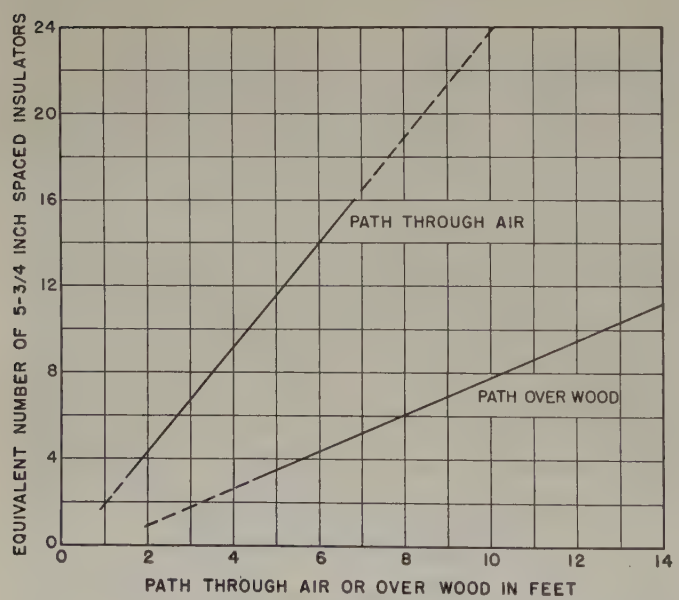


Figure 6. Curves for converting wood and air insulating media to equivalent insulators

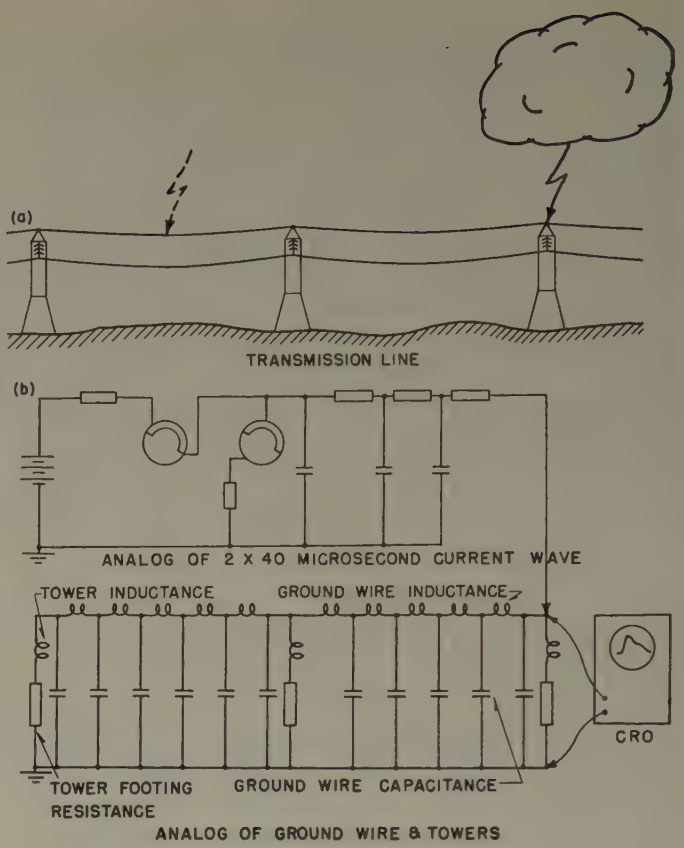


Figure 7. (a) Lightning surging transmission line, and (b) current wave analog surging transmission line analog

Example III. A transmission line is being constructed in a territory where the isoceraunic level is 30. The line will be shielded by ground wire and it is desirable to insulate the line so that outages due to lightning will be limited to 2.0 per 100 miles per year. A knowledge of existing lines in the territory indicates that tower footing resistances of 20 ohms can be obtained economically. Due to the choice of towers and conductors the average span will be 800 feet. The conductors and ground wire will be sagged to provide a midspan clearance of 18 feet. How many insulators are required to limit the outage probability to the desired number?

From Figure 1*i* the outage probability for strokes to midspan is 1.0 outages per 100 miles per year. The outage probability for strokes to tower must be 3.0 so that the overall outage probability will be 2.0 outages per 100 miles per year. From Figure 1*d*, the probability curves for 800 foot spans, nine insulators are needed for an outage probability of 3.0 when the tower footing resistance is 20 ohms. Thus nine insulators should limit the outage probability to 2.0 per 100 miles per year.

BASIS FOR GENERAL CURVES

Computer Study. To determine the tower-top and midspan potentials for strokes entering at those points respectively, a typical transmission line was set up on the Anacom[6]

(electric analog computer). Stroke currents were applied at tower and midspan and the corresponding potentials measured.

The computer setup is shown in Figure 7, in which part *a* shows the line being represented and the stroke locations assumed. In part *b* is shown the analog or equivalent circuit of the transmission line at the bottom, and the analog of the stroke, or surge current generator at the top. It will be noted that only the ground wire, tower, and footing constants are represented, the phase conductors having little effect on the ground wire potentials to ground caused by the stroke. Later the coupling is considered in determining the resulting voltage from ground wire to phase conductor.

Table I. Typical Values From the General Curves

Lightning Flashovers Per 100 Miles Per Year for an Isoceraunic Level of 30

Line Class	Tower Footing Resistance (Ohms)	Span Length (Feet)	Midspan Clearance (Feet)	Figure 1	Monteith[1]
33-kv wood-pole	10	200	10	0.6	
BIL = 700 kv	50	200	10	6.0	
Equivalent insulation = 7					*
5¾-inch spaced insulators	10	400	12	1.1	1.5
	50	400	12	9.5	4.0
132-kv steel-tower	10	600	16	0.6	1.0
BIL = 930 kv	50	600	16	5.0	2.5
Equivalent insulation = 10					**
5¾-inch spaced insulators	10	1,000	24	0.9	1.2
	50	1,000	24	7.6	3.5
220-kv steel tower	10	1,000	24	0.5	0.7
BIL = 1,600 kv	50	1,000	24	2.0	1.5
Equivalent insulation = 18					
5¾-inch spaced insulators	10	2,000	30	1.2	1.4
	50	2,000	30	3.7	3.4

* 6.8 for stroke to tower; 1.1 based on midspan, method not given for combining in case of non-co-ordination. Practice has been to average when estimates for tower and midspan not too far apart.

** Similar to *.

In the operation of the Anacom, the forcing function which is the stroke surge current in this case, is repeated periodically so that the solutions, that is the tower-top and midspan potentials, can be displayed on a cathode-ray oscillograph for observation and measurement. They are photographed for permanent records. Typical records of the stroke current waves and of the tower-top and midspan potentials are shown in Figure 8. Impedances in the transmission line analog are low compared with those in the current wave analog so that the line parameters can be varied over the desired range without altering the stroke current. In general, sufficient pi sections are used for the ground wire representation so that further subdivision has negligible effect on the results. Also a sufficient number of spans is represented so that further spans have a negligible effect. Advantage is taken of symmetry so that the line on only one side of the stroke need be represented.

Analysis Based on Computer Study. The outage probability curves were obtained from the results of the computer study in the following manner. To determine the insulators required to prevent flashover for any particular value of stroke current to tower the following relationship was utilized.

Insulation strength = stroke current × tower top potential per unit stroke current × (1 minus coupling)

For this insulation strength the number of insulators then was determined from the insulator curves of Figure 9. The probability for this stroke current is given in Figure 2. Thus for a particular span length and tower footing resistance, the insulators required for a particular permissible stroke current and hence for a particular outage probability were determined. Making similar calculations for various stroke currents the outage probability curves for strokes to tower, Figure 1*a* to *h*, were determined.

Using the similar relation

Insulation strength required at midspan = stroke current × midspan potential per unit stroke current × (1 minus coupling)

the required midspan insulation for a given stroke current was obtained and converted to air spacing by referring to the rod gap characteristics, Figure 9. The resulting outage probability and permissible stroke current for midspan strokes were plotted in Figure 1*i* and *j*.

Basic Parameters. The stroke current probability curve given in Figure 2 is essentially the data of Waldorf[2] except that it has been modified slightly in the higher current region to allow for strokes up to 200,000 amperes. The reason for using these data rather than averaging other field data is that the figure of approximately 100 strokes per 100 miles per year for an isoceraunic level of 30, which is used

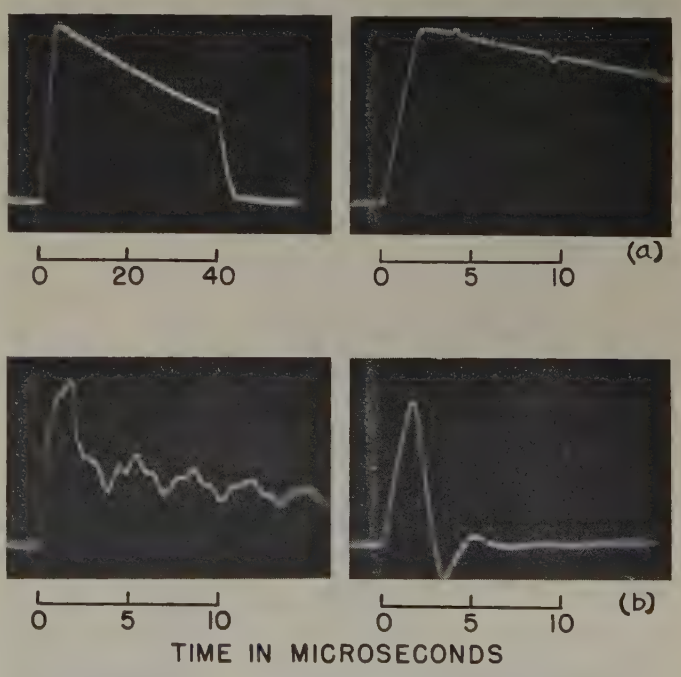


Figure 8 (a). A 2×40-microsecond current wave, and (b) typical tower-top and ground wire potentials, 1,600-foot span, 10 ohms tower footing resistance

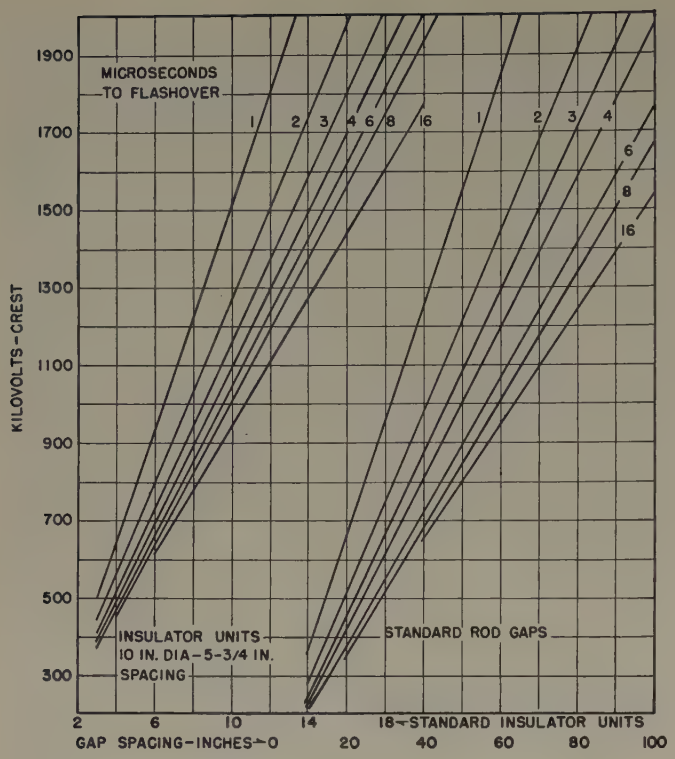


Figure 9. Characteristics of insulators and rod gaps

All values are based on positive waves and corrected to standard atmospheric conditions

to convert the percentage distribution curve to actual strokes per hundred miles exceeding certain values is based on these same data. However, for the more important high stroke current region, this data was in close agreement with the field measurements of stroke currents to wood pole lines.[7] A 2 by 40 microsecond current wave was used throughout this study as representative of the more severe lightning stroke currents of importance in estimating the lightning outages of transmission lines.

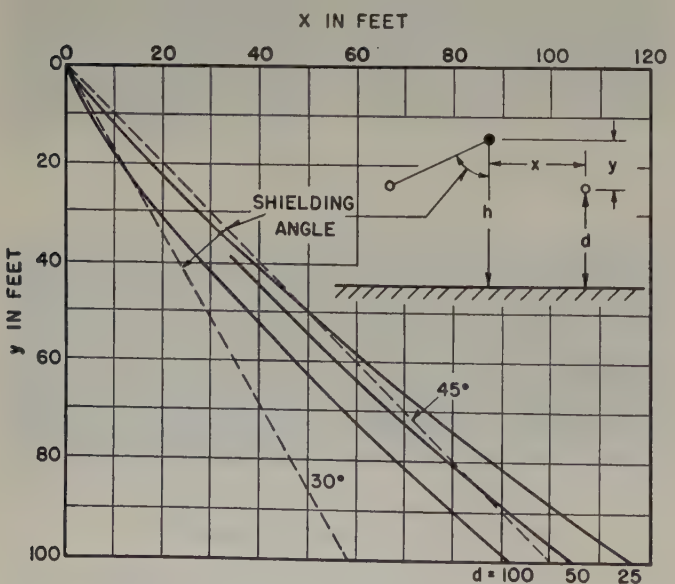


Figure 10. Configuration of shielding wire with respect to protected phase conductors for 0.1 per cent exposure

A single ground wire providing 100 per cent shielding[8] is assumed, the performance of a line with two ground wires being very slightly better. Outages due to imperfect shielding are additive to those caused by flashovers which are given in the general curves. Figure 10 shows the configuration of ground wire and phase conductors for a 0.1 per cent exposure.

The tower inductance of 20 microhenries, used throughout the study, represents a steel tower roughly 100 feet high or a wood-pole 50 feet high with a single down lead.

The geometric mean of electromagnetic and electrostatic coupling factors[9] was used, the latter being based on the corona radius at the voltage involved.

CONCLUSIONS

The general curves give results which are in accord with practically all of the published information on actual line performance. They are also in general agreement with the previous curves of Monteith except for the short spans and high tower footings where some changes are required. In general it is known that 33-kv lines with *BIL* of 700 kv and 10-ohms tower footing resistance result in two or three outages per 100 miles per year. The 132-kv lines of usual lightningproof construction will have about one outage and 220-kv lines with overhead ground wires and low tower footings are practically lightning proof, having a small fraction of one outage per 100 miles per year. Table I shows the predicted values from the new estimating curves for several typical cases, together with values from the earlier curves of Monteith. It will be noted that the new curves show slightly fewer flashovers for the more important case of 10-ohms tower footing. They indicate considerably more flashovers with high tower footing since the stroke current treatment allows for no suppression of the stroke current by the high footing resistance.

The general curves may be used for estimating the performance of existing transmission lines or may be used for comparing the relative merits of changes proposed to improve the lightning performance of existing lines. The curves also may be used for estimating the insulation requirements of lines being designed for a predetermined lightning performance.

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Continuous Winding Temperature Tests Under Load

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IN the standard method for making temperature tests of transformers, the average winding rises are computed from resistance measurements taken after shutdown. This procedure becomes inaccurate when high or rapidly changing temperatures are involved, as in rated-load tests on certain dry-type transformers or in overload tests on oil-immersed apparatus.

The latter case is of particular importance because the inherent, short-time overload capacity of any transformer may be utilized to carry peak loads without undue loss of life, particularly if properly co-ordinated thermal protective devices are employed. To permit such use to the fullest possible extent, however, an accurate knowledge of thermal characteristics of transformers under overload conditions is required. Typical heating curves, from which these characteristics may be obtained, are shown in Figure 1, in which the differential D and the steady-state value D_f are average winding rises above oil temperature.

Since the standard test procedure does not furnish such data with sufficient accuracy, other techniques have been tried; for example, the use of thermocouples embedded in the windings or the extrapolation of values obtained from continuous tests at moderate overloads. These other methods, however, require special apparatus or laborious calculations and still are limited in accuracy and application.

The limitations of conventional tests of winding temperatures have led to the development of an improved method for the evaluation of readings taken after shutdown. By this method, more accurate results for the temperature at shutdown and for the heating curves are obtained on the basis that the exponential function of simple winding transients can be used without change when the effect of the temperature coefficient is included, that is, when the heating and cooling cycles have different time constants instead of a single value t_w as shown in Figure 1. Computations can be based on a cooling curve or, if the thermal capacity of the winding is known, on a single test point, and can apply even to the complex case of liquid-filled units. Nevertheless, the method is laborious and is often not accurate enough, like all other indirect measurements.

For this reason, a new technique has been developed which measures winding temperatures while the transformer carries its load. In this technique, the use of a Wheatstone or Kelvin bridge requires that direct current is supplied to windings under a-c excitation. In order to avoid a harmful coupling between a-c and d-c circuits, the bridge is applied to winding terminals of equal a-c potential, and the coils are connected so that no direct voltage appears between a-c supply terminals.

Figure 2 represents a typical circuit of this kind for a simultaneous test of both windings of two single-phase transformers. A-c line voltage is supplied to terminals m and n of the parallel-connected high-voltage sides which also have midtaps a and b. Load current flows through terminals p and q to a series connection of the low-voltage sides, which is split into two equal parallel circuits with midpoints c and d. Then a and b, as well as c and d, are at equal d-c potentials, and can be connected to two separate bridges, distinguished as high-voltage and low-voltage bridges, for a d-c test of the corresponding windings. At the same time, m and n, and also p and q, are on the same a-c potentials, as required.

Residual alternating currents entering the bridge should be kept away from the galvanometer G by a small filter F, as shown in Figure 2, while a protection against accidental voltages may be provided by cutouts.

The circuit, Figure 2, can be modified to permit the test of polyphase windings and of transformers containing circuit breakers. These connections are considerably simplified for measurements at heavy overloads in which the core losses become so small, as compared with the total losses, that the line voltage can be omitted and load current only is applied, as in the conventional short-circuit test of copper losses.

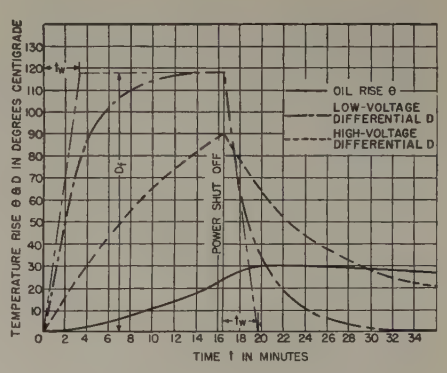

Figure 1. Temperature rises in a small single-phase distribution transformer at 400 per cent load

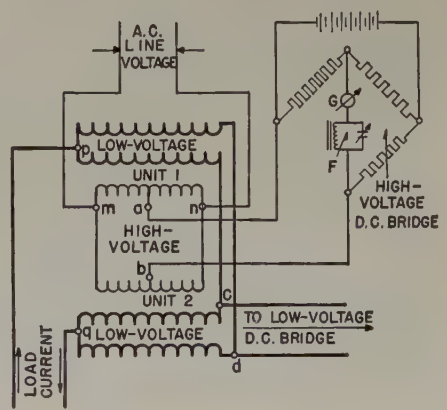

Figure 2. Circuit for a simultaneous test of high-voltage and low-voltage winding temperatures in single-phase transformers under load and line voltage

Digest of paper **48-290**, "Measuring Transformer Winding Temperatures Continuously With the Transformer Carrying Load," recommended by the AIEE transformer committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Ratings of Diesel-Electric Locomotives

D. R. CAMPBELL T. J. WOODS
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THE DIESEL-POWERED locomotive has emerged as one of the most efficient and economical forms of motive power available to industrial and railway users, ranging in size from 100 to 8,000 horsepower. This versatility is due largely to the electric transmission system by means of which the relatively constant torque of the engine is transformed to the varying torque required at the driving wheels for effective utilization of full engine horsepower over the operating range of the locomotive.

The use of the Diesel-electric locomotive has brought with it a problem heretofore not encountered by railroad personnel trained in the use of the reciprocating steam locomotive, that is, the ability of the electric transmission to work at overload values of current for definite periods of time. This feature may be used to increase the trailing loads hauled over a given section of the railroad.

Various methods have been devised to determine the maximum tonnages which may be handled for short periods of time, thus utilizing the electric equipment to its fullest capacity. The temperature of the traction motors is difficult to measure in service, as it means stopping the locomotive at some point and applying temperature measuring devices. This method is unacceptable in scheduled service and is restricted to special testing of locomotives. To date, there is no practical instrument to indicate the temperature of the electric equipment to the locomotive engineer.

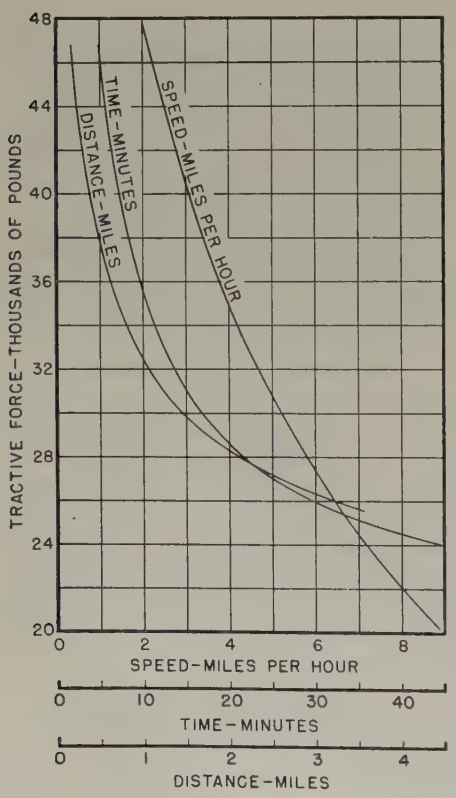

Figure 1. Curves for determination of tonnage tabulation

Plotted for a 650-horsepower 80-ton locomotive

Such an instrument would not completely solve the problem. It is desirable to know at the starting point what tonnage the locomotive is capable of hauling over the profile. An accurate temperature-indicating device will inform the operator when to reduce the load on the electric apparatus. However, at this point, a slowdown or stop may be impractical from the railroad's point of view.

There are, in general, two types of service performed by locomotives in railway work. These are classified as switching and road service. Because of the difference in duty cycle, a different method is used in each class of service to determine hauling capacity.

The duty cycle imposed in normal switching service is usually not of a severe nature. The runs are relatively short with considerable standstill time. Thus, current is flowing through the motors only a small percentage of the time. Experience has shown that a continuous tractive force rating of 12 to 15 per cent of the weight on drivers is sufficient to handle typical switching operations without danger of overheating the electric apparatus. On this basis, tonnage charts may be prepared showing the maximum loads that can be hauled on grades of definite length. A table such as this, derived from curves like those shown in Figure 1, will be of considerable use on a switching locomotive assigned to general yard and transfer service.

Road service is different from switching service in that the locomotive may work near full rated horsepower for a considerable length of time. Working at a higher load factor requires that the continuous tractive force be equivalent to 18 to 20 per cent adhesion. With this value the electric-equipment maintenance should hold to a reasonable level.

The heating and cooling of traction motors and generators can be determined by test. Using these, and a knowledge of the profile, it is possible to calculate the maximum tonnage the locomotive is capable of hauling over a given section of the railroad. This method insures that the locomotive will be used effectively, yet protection from overheating is assured. Also, the possibility of unscheduled stops on the mainline due to overheating is eliminated.

It is recognized that the thermal capacity inherent in electric apparatus greatly increases the value of the electrically propelled vehicle, and acceptable methods of evaluating this characteristic should be available for general use. The methods presented herein are offered as a possible solution for determining hauling capacities or as a foundation on which to base a practical system acceptable by all concerned.

Digest of paper **48-300**, "Short-Time Ratings of Diesel-Electric Locomotives," recommended by the AIEE land transportation committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Voltage Surges in Relay Control Circuits

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DEVICES which depend for their operation on the linking of magnetic flux with a current-carrying coil produce a transient voltage in their coils when they are de-energized suddenly. The magnitude and duration of such a transient depend on many design and operating factors. Included are size, shape, permeability, and resistivity of the magnetic material, as well as the maximum area to be surrounded by individual eddy currents, the magnitude of the exciting force, coil voltage, number of turns, and the speed of current interruption. In general, the large devices initiate transients having much more energy and longer duration but often of lower voltage than do small devices such as relays.

With one terminal of a coil held at normal circuit-to-ground potential by the power source, and with a transient induced in the coil, the voltage to ground increases progressively through the coil to the other terminal. This terminal, the contact of the interrupting device connected to it, and the intervening wire are subjected to the entire surge voltage. Together with the adjacent coil turns they may be considered as the area of danger. If the power supply were grounded solidly, a breakdown in this danger area would short-circuit the coil and suppress the discharge transient.

It is prevalent practice to obtain control power from a storage battery which is grounded only through a high-resistance ground detector. When a breakdown occurs in the danger area of any circuit, the ground detector resistance does not have sufficient capacity to hold the battery at its normal potential to ground and the entire d-c control of a station may be raised to a value of several hundred and perhaps in excess of 2,000 volts above ground. A voltage of this magnitude may cause serious injury to anyone who happens to be in contact with a normally low-voltage control circuit. Too, in seeking a return path to ground, it may break down insulation, open load-carrying circuit breakers, or close open ones.

Two general methods are proposed to control these transient voltages. The first one consists of paralleling each large inductance with a voltage suppressing device.

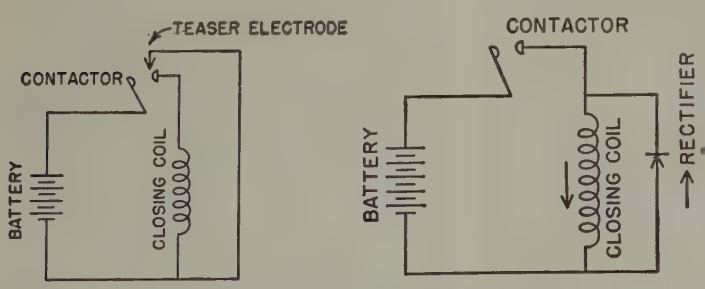

Figure 1. A "teaser" electrode and a rectifier used to suppress discharge voltages

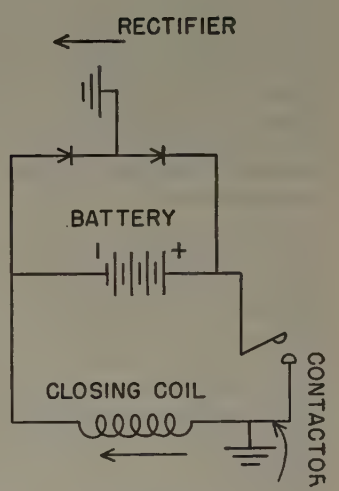

Figure 2. Protective rectifier applied to control bus to limit discharge voltage transient after initial breakdown

An ordinary resistor of suitable value will hold the voltage to a safe value, however, it draws considerable current from the battery during the energized period, increasing voltage drop in both the battery and the control wires. A silicon carbide disk having a nonlinear current voltage characteristic can be used. It does not draw appreciable current during the energized period but in feasible sizes will not limit the transient voltage of a large solenoid to less than 300 to 400 volts. A third electrode in the contactor called a "teaser" electrode, located so that it will be in the arc path as soon as the contacts separate and connected to the other terminal of the coil, satisfactorily limits the surge voltage. It draws no current during the energized period but may cause a battery short circuit and does increase erosion of the contactor contacts and arc chute. A dry-plate rectifier paralleling the inductance limits the discharge voltage to about one-half normal battery voltage and does not draw appreciable current during the energized period. Experience covering several thousand application years with practically no trouble makes this method highly preferred. Figure 1 shows circuits using the "teaser" electrode and the dry-plate rectifier to suppress discharge voltage.

The other general method does not suppress the transient at its source but does confine it to the danger area of the operating device. It consists of one-half wave rectifier with its mid-point grounded connected across the control battery, as shown in the circuit of Figure 2. If the insulation of any inductive device fails to ground during its discharge, the rectifier provides a low-resistance return path for the discharge current thus localizing and effectively suppressing the transient. Requiring but one rectifier per station, this method can be easily inaugurated.

Digest of paper **48-309**, "Voltage Surges in Relay Control Circuits," recommended by the AIEE relay committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Conference Papers Digested for Winter General Meeting

These are authors' digests of most of the conference papers presented at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. These papers are not scheduled for publication in AIEE TRANSACTIONS or AIEE PROCEEDINGS, nor are they available from the Institute.

Calculation of Flux Distributions with Saturation; *H. Poritsky (General Electric Company, Schenectady, N. Y.).*

Methods for solving problems in 2-dimensional flux distributions taking saturation into account, are considered in this paper and the analysis is based on the following assumptions: There exists a definite relation between H and B given by a single curve in the (H,B)-plane; this curve may correspond to a curve bisecting the various hysteresis loops, or to a particular branch of one such loop. Rotary hysteresis is neglected, and the directions of the H, B, are assumed to coincide. The material is assumed to be laminated and no eddy current phenomena are involved. Thus alternating fields are not excluded, but at any instant they agree with the static field corresponding to the instantaneous magnetomotive forces.

Four methods of solution are

1. A numerical method of approximate integration of the proper nonlinear differential equations.
2. A graphical or flux plotting method.
3. The use of the d-c board.
4. The "hodograph" method.

The differential equations satisfied by the magnetic potential φ and the flux function ψ are

$$\frac{\partial}{\partial x}\left(\mu\frac{\partial\varphi}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial\varphi}{\partial y}\right)=0$$

$$\frac{\partial}{\partial x}\left(\frac{1}{\mu}\frac{\partial\psi}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{1}{\mu}\frac{\partial\psi}{\partial y}\right)=0$$

where $\mu=B/H$ is a function of H or B, and

$$H=(\varphi_x^2+\varphi_y^2)^{1/2},\quad B=(\psi_x^2+\psi_y^2)^{1/2}$$

The numerical method consists in replacing the differential equations by approximating finite difference equations over a lattice of points, guessing a solution, substituting in the difference equations, obtaining "residues," and improving the initial guess by "relaxation" methods until the residues become small.

The graphical method is based on the fact that the equipotentials and flux lines, when drawn for values of φ and ψ differing by constant amounts $\Delta\varphi$, $\Delta\psi$, divide the plane into small rectangles such that when one side Δn is given, the other side Δs is determined as a definite function of Δn obtainable from the (H,B)-curve.

The d-c board method utilizes an analogy to the conduction in a plate whose conductance is a proper function of the current density. If the electric potential is made proportional to the magnetic potential φ, then the conductance is proportional to the permeability μ. If the electric potential is made proportional to the magnetic function ψ, then the resistance is made proportional to the permeability μ. The approximating finite difference equations (mentioned under the numerical method) correspond to the Kirchhoff equations for the currents in a network joining the lattice points of the difference equations. The resistances at first are set arbitrarily, the voltages are read, the current densities $I=(I_x^2+I_y^2)^{1/2}$ are computed, and the resistances reset as a proper function of I; a possible alternative procedure is to adjust the resistances as a proper function of the voltage gradient $E=(E_x^2+E_y^2)^{1/2}$. The process is repeated until no further changes result.

The "hodograph" method is well known in the field of flow of compressible fluids where it converts the nonlinear flow equations in the physical plane into a linear system in the "hodograph plane," that is the plane in which the velocity components are used as co-ordinates. By establishing an analogy between the magnetic problem and the fluid flow problem, this method can be carried over to flux distribution problems, where it shifts from the original physical plane either to a plane in which H_x, H_y are co-ordinates, or to a plane in which B_x, B_y are co-ordinates.

Tables of Green's Functions, Fourier Series, and Impulse Functions for Rectangular Co-ordinate Systems; *J. J. Smith (General Electric Company, Schenectady, N. Y.).*

Tables of Green's functions, Fourier series, and impulse functions have been prepared materially to reduce the work in solving partial differential equations encountered in engineering and physics. They allow us to solve such equations by obtaining the results directly from tables which can be used in a similar way to tables of integrals.

The Green's function, which is the potential due to a single point charge within a given space with assigned conditions on the boundaries of the space, is used as the fundamental solution connected with that space. That is due to the fact that when the Green's function for any space is known, the solution for other conditions usually encountered generally can be found by the use of auxiliary theorems. This makes it possible to avoid solving the differential equation itself for different types of conditions, as commonly is done in textbooks at the present time. This crystallization of the solution into a single function, the Green's function, together with the ensuing possibility that such results may be tabulated fairly simply, results in a great economy of labor in connection with the solution of such partial differential equation.

With regard to Fourier series, they, of course, are connected closely with the solution of partial differential equations, so it is natural to expect that the quantities which have been tabulated for the Green's function should be also available for use as a tabulation for Fourier series; the same fundamental expression serves in both cases.

With regard to impulse functions, these have been coming into use in the literature for quite a long time and have been used by many authors. They are not recognized as functions by the mathematicians at the present time. They are extremely useful, however, because although they may appear very complex as mathematical expressions, they represent an extremely simple physical concept, which is that their value is zero at all points except the point at which there is an impulse. Thus, the integral of the impulse function between any two points which does not include this impulse is zero, and it is unity if the interval includes the impulse. As would be expected, they are very closely allied to Fourier series and also to Green's functions. Thus, the expressions already worked out for the Green's functions may be used directly for tabulation of impulse functions.

The afore-mentioned tables are based on a paper by the author and may be checked readily by substituting appropriate sine and cosine functions in the formulas given in that paper. The tables only cover applications to rectangular co-ordinates.

In the tables the differential equations for Green's functions, and their solutions are given for the following cases: steady state point source one, two, and three dimensions, and for the instantaneous point source one, two, and three dimensions.

Large Screen Projection Television; *Ralph V. Little, Jr. (Radio Corporation of America, New York, N. Y.).*

Two basic systems of large screen television are being evaluated by Radio Corporation of America through a series of practical tests being conducted in a joint experimental program with Warner Brothers and 20th Century-Fox. One is the direct projection system by which high brilliance kinescope images are projected through an efficient reflective optical system; the other, an intermediate film system using standard motion picture projection technique, after television images have been photographed on motion picture film and suitably processed for projection.

The direct projection television system consists of three major elements: the projection kinescope which is the source of the light image; the optical system which projects the image onto the screen; and the screen from which the final image is viewed. The three elements must be designed into a co-ordinated system to provide the maximum over-all efficiency.

The alternate system of large screen television projection, which was referred to earlier as the intermediate film system, also consists of three major units. The first is the television recording unit with a high quality television monitor and a special 35-millimeter motion picture camera, the second consists of a high-speed film processing machine, and third, the conventional 35-millimeter theater film projector. Such a system which can be so integrated that the film runs through the complete cycle at the

conventional speed of 90 feet per minute, completing the cycle so that the elapsed time between the image appearing on the kinescope and its projection on the viewing screen is less than one minute.

The two television systems now can be summarized in the following tabulation giving the advantages and disadvantages of each.

Direct Projection	Intermediate Film
Method	
High intensity projection kinescope with highly efficient reflective system and screen	Motion picture recording of television image followed by rapid film processing and projection in standard film projector
Advantages	
1. Appeal of immediate reproduction	1. Uses standard film projection equipment with present screen brightness
2. Simplicity of operation of equipment	2. Programming can be scheduled to best advantage
3. Low operating expense	3. Permits editing of film
	4. Permanent film record made available for successive shows and syndication to small theaters
Disadvantages	
1. Optical system characterized by short throw	1. Cost of installation
2. Special screen required	2. Operation cost: (*a*). Film (*b*). Processing
	3. Sound must be recorded

Performance-wise the large screen projectors are now limited by the quality of the signals available for projection. Experience has shown that, large screen images produced by either the direct or the intermediate film system are entirely acceptable to critical audiences.

Television systems for the theater will no doubt be on present RMA standards, but programmed by their own private system through the use of microwave relay. The equipment and techniques of operation will continue to be improved to bring high quality programs to the theater.

The Design of D-C Motors for Use in Automatic Control Systems; *Paul Lebenbaum, Jr.* (*General Electric Company, Lynn, Mass.*).

The increased use and accuracy of automatic control systems for industrial and military applications has made it essential that system component be re-examined in terms of over-all system operation. It is the purpose of this paper to study the application of d-c motors in these systems in order to:

(*a*). Determine the motor constants which affect system performance.

(*b*). Convert the important motor system constants into design factors, such as armature diameter and length, flux and copper densities, and so on.

(*c*). Determine the motor design which will give optimum over-all system performance.

When a separately excited shunt-wound d-c motor is used as the output number of a closed-cycle automatic control system, the motor time constant is the motor constant which the system designer uses in calculating the stability, allowable amplification, accuracy, and speed of response of the system. It is defined as the time in seconds to accelerate the motor and load inertia to 63.2 per cent of its final speed when a direct voltage of constant magnitude is applied suddenly to the motor terminals. Optimum system design requires that the motor time constant be as small as possible, since large values of this factor result in stability problems, which force the designer to reduce the allowable amplification of the system, and thus reduce its accuracy.

The motor time constant is a function of the motor armature circuit resistance, the inertia of the motor and the load, and the torque and generated voltage constants of the motor. When this constant is converted into motor design terms, it is found that it is primarily a function of the motor pole face flux density; the flux density at the root of the armature tooth; the ratio of armature slot depth to diameter, and pole arc to pole pitch; and the ratio of commutating field to armature conductor copper densities.

A study of the equations derived in this paper reveals that the following points should be considered in designing a motor with a minimum time constant:

(*a*). The flux density at the root of the armature tooth should be high.

(*b*). The armature slot depth should have a value as close to one-eighth of the armature diameter as possible.

(*c*). The ratio of pole arc to pole pitch should be large.

(*d*). The ratio of armature slot copper arc to armature slot arc should be high.

(*e*). The ratio of connecting field to armature conductor copper density should be small.

(*f*). The ratio of armature diameter to length should be small, when the load inertia is negligible. When the load inertia is not negligible, an increase in this ratio actually may give a smaller motor time constant. Under this condition a larger value of the ratio may result in a greater decrease in armature circuit resistance than the corresponding increase in motor and load inertia, and thus in a net decrease in time constant.

Limitations in Design of D-C Adjustable-Speed Motors; *L. G. Opel* (*Westinghouse Electric Corporation, Lynn, Mass.*).

An adjustable speed motor is one in which speed control is obtained by varying the shunt field current of the motor. The four factors considered as limiting the operation of the motor are commutation, speed regulation, heating, and maximum safe speed mechanically.

An analysis of Lamme's equations will show how the various constants of the motor affect commutation. By careful study and calculation, the various proportions of the machine, such as slot width, slot depth, armature diameter, length of armature core, number of commutator bars, number of armature turns per coil, can be determined for best performance of the motor.

The speed regulation of the motor will vary, depending upon the field strength. The armature distortion of the motor causes the regulation to be larger at weakened fields because of series field turns added to make the motor stable at 150 per cent base speed.

Special pole notches can improve speed regulation by reducing the effect of armature distortion. The use of compensating windings gives greatly improved speed regulation and gives other benefits in addition. Special windings on the main field poles are in use to give better speed regulation.

The losses and ventilating air flow through the motor vary with the motor speed. If motor is to operate for a long period of time at any given speed, the heating at that speed will have to be considered.

A New Device for Calibrating Watt-Hour Meters; *H. F. Robison, W. H. Wickham* (*Commonwealth Edison Company, Chicago, Ill.*).

A new device has been developed to provide a better means of calibrating watt-hour meters, particularly in the field. With this device, the field testing of watt-hour meters is made much faster and easier as compared to the conventional methods of counting and timing of disk revolutions because an instantaneous and continuous visual indication of meter accuracy is obtained. In general, closer adjustment to correct registration is obtained than by the methods involving successive trials. The device is portable. No special disks, disk markings, or the like are required for its application.

Other methods, such as the stroboscopic methods and automatic counting of revolutions, have been developed for laboratory or shop use and have some of the same advantages. However, these methods are not applicable to field testing because they require that the meters be mounted in a special stand, or jig, and furthermore, the equipment is too elaborate and cumbersome.

The new device compares the speed of the disk of the meter under test with that of a standard watt-hour meter by photoelectric means. An instantaneous and continuous comparison of speeds is indicated on the screen of a cathode-ray tube.

Both the standard and the test watt-hour meters are equipped with a light source, a system of lenses and mirrors, and a photoelectric cell. This test unit is permanently mounted on the standard and temporarily mounted on the meter under test. Serrations on the disk of each meter interrupt the light on the photoelectric cells as the disks rotate. Serrated disks are standard on all modern watt-hour meters. The variation of current in the photoelectric cell on the standard meter is utilized to control the horizontal sweep circuit of a cathode-ray tube, and on the test meter to produce a vertical deflection on the screen. The resulting trace is stationary when the disks of both meters are rotating at the same speed, and moves across the screen when the two speeds differ. The direction of travel determines whether the meter under test is fast or slow. It is not essential that the disk speeds be the same as long as the frequencies of the periodic currents from the photoelectric cells attached to the meters are integral multiples, one of the other. This permits the use of the same standard meter to calibrate meters having different numbers of disk teeth and different disk constants. The action of the trace is used to obtain an "as found" check by varying the voltage on the standard, by means of a tapped autotransformer with suitable vernier adjustment, to match its speed to that of the meter under test. It is used also to obtain correct registration of the meter under test by resetting the standard for the desired registration and by changing the adjustments of the meter under test to match its speed to that of the standard.

The new device has been used for calibrating station watt-hour meters for a period of about eight months. It has been found that accurate calibration by this method requires only one-third as much time as the conventional method of counting disk revolutions. The device detects erratic disk motion such as caused by defective bearings and registers, or by foreign material on the disks or magnets much more readily than the conventional method. The tester can observe the action of the trace on the cathode-ray screen over long periods of time with no appreciable eye strain.

The sensitivity of the detecting device is such that meters can be calibrated with an accuracy of 0.1 per cent.

Power Cable Distribution for a Gulf Coast Chemical Plant; *B. J. Nankervis (Texas Division, The Dow Chemical Company, Velasco, Tex.), F. S. Glaza (Texas Division, The Dow Chemical Company, Freeport, Tex.).*

Lead-covered cable has been used extensively for power distribution both underground and overhead for many years, and information is readily available on the performance of cable with this type covering. The use of cable with rubber or synthetic rubber jacket in place of lead covering has not been so wide-spread, and therefore it is the purpose of this paper to describe an installation in which this type cable has been used for aerial power distribution at 15 kv for eight years.

The Texas Division of The Dow Chemical Company has located near Freeport, Tex., two large chemical plants constructed in the war years of 1940–43 for the production of magnesium, chlorine, caustic soda, ethylene, propylene, ethylene glycol, styrene, and other products. Due to the processes involved, large amounts of power are generated and used and the plants are running at present with generation in excess of 200,000 kw. With minor exceptions, this power is distributed by an aerial cable system at 15 kv, grounded neutral, 60-cycle alternating current.

The cable used for power distribution has a copper conductor, varnished cambric insulation, natural or synthetic rubber jacket, and a 0.025-inch-thick bronze interlocking armor overall. The 3-conductor cable has a 16/64-inch-thick insulation with a copper shielding tape between insulation and jacket. The original single-conductor cable has 16/64-inch-thick insulation and is not shielded; however, cable of revised specifications has 21/64-inch-thick insulation and is shielded.

The cable is run outdoors overhead and is supported by one-half-inch bronze messenger and bronze cable rings. Double-armed *H*-type structures are used with 55-foot class *1* treated southern yellow pine poles. These structures are designed to withstand 125 mile per hour wind velocities in order to withstand hurricanes experienced on the Gulf Coast.

Performance of the 3-conductor cable has been quite satisfactory for in eight years of plant operation, with approximately 56.9 mile years of cable service, there have been only six failures. This gives an average of 0.106 failure per mile year for the cable. Of the six failures, the first two are thought to be the result of an overload condition that existed for a short time, and the remaining four failures were attributed to defective workmanship in cable manufacture.

The performance of the single-conductor cable has not been as good as that of the 3-conductor cable for in eight years of plant operation with approximately 46.8 mile years of cable service, there have been a total of 22 failures. This gives an average of 0.47 failure per mile year for the cable. These failures were due to absorption of moisture into the insulation. The rubber hose jackets and, in some cases, the Buna *N* synthetic rubber jackets were found to be in a deteriorated condition due to the effects of ozone and corona.

For corrective measure the specifications of the single-conductor cable was changed to include a copper shielding tape between the insulation and jacket, to provide for a jacket of polyvinyl chloride composition, and for an increase of insulation thickness from 14/64 inch to 21/64 inch. This latter change was made to provide for the possibility of transient high-voltage conditions occurring on feeders supplying rectifier station loads. Cable manufactured according to the revised specifications has been in service for two years without a failure and it is expected that the performance of this cable now will equal that of the 3-conductor cable.

The results of eight years experience with an aerial cable system for primary power distribution for the Dow Chemical Company plants located on the Gulf Coast may be summarized as follows:

1. There have been no outages of the system due to lightning or to storms.

2. There have been no failures due to contaminated plant atmosphere.

3. There have been no accidents to personnel due to the power system.

4. The avoidance of an underground system has eliminated problems of electrolysis, stray currents, damage through the spilling or seepage of chemicals, and the possibilities of dangerous accumulation of explosive gasses in cable vaults.

5. Cable failures have been at the rate of 0.106 failure per mile year for the 3-conductor cable. Difficulties with the single-conductor cable have been corrected and no failures have occurred in two years operation with the new cable.

In conclusion it may be stated that varnished cambric cable with polyvinyl chloride jackets are now satisfactory for 15-kv aerial power distribution. However, it is expected that the trend will be toward the use of synthetic compounds for the insulating medium for aerial systems at 15 kv as these compounds are improved further. With proper resistance to corona and ozone effects, this type insulation would have the advantage of being simple in construction, would be quite flexible, and would have greatly increased resistance to moisture absorption over present-type jacketed cables.

The Economics of Fluorescent Lighting; *Richard G. Slauer (Sylvania Electric Products Inc., Salem, Mass.).*

The evaluation of a lighting system should be in terms of specific gain—less production spoilage, greater store sales, better office morale. Only if these can be converted into a common denominator such as dollars can a true economic analysis be made. Although recognizing the validity of this approach, it is assumed in this study that good lighting is justified and therefore the important decision is the form the lighting may take.

Economic considerations have greater importance in application trends of fluorescent lighting than they did for incandescent lighting for three basic reasons. The first is that incandescent lighting is still available and widely used and thus represents a direct competitor. This contrasts with the almost exclusive field enjoyed by incandescent lighting during its greatest development period. The second reason that the initial investment for fluorescent lighting is appreciably higher and therefore must be justified by operating economies, better lighting quality, or both. Third is the lack of interchangeability of different fluorescent lamps. This condition, primarily a length and circuit accessory problem, demands certain prior decisions which while customary in many fields are a new approach in lighting.

There is no uniform practice for determining the cost of lighting but the most common is based on annual costs for a given foot-candle level. Included in such costs are four major items: lamps, energy, amortization, and maintenance. On a nation-wide basis, the assumptions required for each of these items provide answers which are so generalized as to be difficult to interpret. Nevertheless trends are indicated and the method is valuable for any specific lighting project. It is recognized also that delivered foot-candles are a narrow criterion. While it is the best available, illuminating engineers feel the real need of a quality criterion as well.

From an analysis of economic data presented for ten different types of fluorescent lamps used in a hypothetical industrial lighting application employing individual luminaires, and similar data for six of these sources used in a strip or row lighting installation typical of many commercial as well as industrial applications (some of the data plotted as related to the 40-watt 48-inch $1^1/_2$-inch diameter preheat fluorescent lamp which represented about 65 per cent of the total demand during the first decade of commercial availability of fluorescent lamps), data conclusions are drawn. They include:

1. Certain characteristics of fluorescent lamps lend themselves readily to the attainment of good quality illumination while incandescent lighting can achieve the same results only by indirect methods which result in appreciable cost penalties.

2. No particular fluorescent lamp is cheaper than any other since every factor which enters into the cost of lighting tends to shift in emphasis with various conditions of application.

3. As most fluorescent lamps are within a narrow cost span, factors to which no general economic value can be assigned often become the determining factor of usage.

Clampers in Video Transmission; *S. Doba, Jr., J. W. Rieke (Bell Telephone Laboratories, Inc., New York, N. Y.).*

A television clamper is a device which samples the departure of the television wave from a reference value during the blanking and/or synchronizing intervals, and adds to the wave a signal which reduces that departure.

This process effectively suppresses low-frequency interference and distortion. However, when the interference frequency ap-

proaches one-half line frequency (15.75 kc) the sampling process breaks down and interference effects will be aggravated. At high frequencies (over 100 kc), the sampling circuit may be made ineffective so that high-frequency interference is unaffected by clamping.

A method for employing the essential components of a clamper within a feedback loop is described as follows. The signal may be distorted at the input and may be distorted further by any element in the forward path of the feedback loop. In the return path the output signal together with its distortion and interference is amplified by a factor, μ, and sampled by the detector during the chosen time intervals. The detector is equivalent to a switch which closes for the duration of the sampling interval and opens between sampling intervals; thereby impressing upon a capacitor the value of the signal during the interval. The signal value is averaged over the sampling interval by means of a resistance-capacitance time constant associated with the charging circuit. This averaging is essential to make the detector insensitive to high-frequency interference.

The output of the sampler is added in reverse phase to the input circuit resulting in a forward gain reduction to distortion and interference by a factor $(1+\mu)$ while at the same time, the picture signal gain is unchanged. In practical circuits μ can be made sufficiently large that low-frequency distortion at the output is reduced to negligible values.

In the forward path of the feedback loop there may be transmission elements of several kinds including nonvideo components such as amplitude or frequency modulators delivering radio-frequency outputs. In these cases, the detector necessarily would involve operations that are the inverse of those of the forward path elements.

In common with all negative feedback arrangements, the problem of stability exists in the frequency range where the feedback ratio is falling off. The high-frequency cut-off is determined by the time constant which provides for sample averaging. An optimum choice of this time constant from an over-all performance standpoint produces a high frequency cut-off within the feedback loop which reduces the feedback to unity at about 64 kc—a frequency low enough to make negligible the phase shift contributions of the other elements in the forward and return paths. The low-frequency stability problem due to cut-off will prove more difficult unless the problem is avoided by maintaining the feedback to zero frequency. This procedure is usually advantageous since it results in d-c stabilization of the output during the synchronizing or blanking intervals. Thus, the radiated amplitude of carrier of a television transmitter could be maintained at a fixed value for the tips of the synchronizing pulses by including the transmitter as one of the forward path elements of the clamper feedback loop.

Furthermore, if d-c stabilization exists at synchronizing pulse intervals it is possible to measure the signal excursion from the chosen reference value at some high-amplitude portion of the circuit, for example, at the output of the amplifier which delivers signals to the detector, by means of a peak rectifier and produce an accurate meter indication of the peak-to-peak video output voltage. Thus, the video equivalent is provided for the program volume indicator which is now standard equipment in sound program circuits.

Effects resulting from the use of clampers are

1. Clampers suppress low-frequency interference by a factor inversely proportional to the frequency of the interference (over 30 decibels at 60 cycles).

2. Clampers permit raising of the low-frequency cut-off frequency by factors of 10 to 65 times compared to nonclamper transmission systems thus reducing the size of low-frequency cut-off elements and permitting the use of video transformers in some cases.

3. Clamping doubles the effects of interference in the frequency range from 2.5 kc to 100 kc. This, ordinarily, is not a limitation.

Resistance Wire Strain Gauges as Elements of the Wheatstone Bridge; *Vincent Petrucelly, Jr. (American Machine and Foundry Company, Brooklyn, N. Y.).*

This paper derives some of the important characteristics of the Wheatstone bridge and presents them in simplified form for direct application to wire strain gauges.

The galvanometer current I_g caused by a strain e, may be expressed as follows:

$$I_g = \frac{Vek_w n}{4(R+R_g)} \tag{1}$$

where

I_g is the galvanometer current, or output current of the Wheatstone bridge
V is the bridge input voltage
e is the strain, or $\Delta R/R/k_w$
ΔR is the change in resistance caused by the strain e
R is the resistance of one arm (all arms are equal)
R_g is the resistance of the galvanometer
k_w is the gauge factor
n is the number of active gauges in the bridge

If the lower part of the bridge contains two fixed resistors R_0, and if the upper part contains two other resistors R, then

$$I_g = \frac{Vek_w n}{2(R+R_0+2R_g)} \tag{2}$$

For optimum sensitivity all arms of the bridge should be equal to each other and to the galvanometer. In most instances the resistances of the arms are fixed by the type of commercial gauges available. The optimum galvanometer resistance is then

$$R_g = \frac{R_1R_2}{R_1+R_2} + \frac{R_3R_4}{R_3+R_4} \tag{3}$$

where R_1 and R_2 are the upper arms, and R_3 and R_4 are the lower arms of the bridge, for the condition where the voltage is impressed across R_1 and R_2 in series. In order to obtain proper damping of the galvanometer it may not be possible to select the optimum galvanometer resistance. However, the resistance of the galvanometer may differ from the resistance of the external circuit by 6:1 with a loss in deflection of only 30 per cent.

If the detector is an infinite impedance device, such as a vacuum tube amplifier, only the open-circuit voltage at the detector terminals is of interest. This may be expressed as shown in the following equation:

$$E = \frac{Vek_w n}{4} \tag{4}$$

where the symbols have the meanings indicated previously. For maximum sensitivity the resistances of the upper arms should equal each other, and the resistances of the lower arms should equal each other, but the upper and lower arms need not be the same.

The General Electric Metals Comparator; *D. E. Bovey (General Electric Company, Schenectady, N. Y.).*

The General Electric metals comparator was developed primarily for use in production quality control. It is a portable electronic device for nondestructively testing metal parts and providing a visible indication if a difference exists between the part being tested and the standard part with which it is compared. It will compare both magnetic and nonmagnetic metals, and will test for uniformity of surface conditions, such as plating, hardness, and case-hardening depth. It also will compare the interior portions of metal parts on the basis of uniformity of composition, hardness, or heat treatment. Average values are indicated.

The metals comparator makes use of the fact that the magnetic and electrical properties of metals are different when there are differences in their physical characteristics. Two alloy steels alike except for carbon content, for example, will differ appreciably in magnetic permeability, and will differ also in electrical resistivity. In the comparator, the effect of an unknown sample on the magnetic field of a test coil or a special test head that is compared with that of a standard, and if there is a difference in the two effects an indication is produced on the face of the comparator voltmeter. The voltmeter thus indicates whether the unknown is like the standard or not.

Some of the interesting recent applications to which the comparator has been successfully applied are

1. The uniformity of the iron plating on soldering iron tips is controlled in a production line.

2. Two freight carloads of mixed steel stock were sorted on the basis of the nickel content.

3. Ten thousand mounting studs were sorted on the basis of weldability. Some of these were made of the wrong material due to an accidental mixture of stock in a stockroom.

4. The uniformity of the surface hardness of lathe beds was tested.

These are only a few of the many applications of the metals comparator.

Power Wiring in Petroleum Refineries; *W. H. Dickinson (Standard Oil Development Company, Elizabeth, N. J.).*

Much of the reliability of an electric system depends on the power wiring. Four types of power wiring used in petroleum refineries are listed in order of descending cost:

1. Cable in conduit or duct.
2. Buried cable.
3. Aerial cable.
4. Open wiring.

Generally, only the first cable in conduit, is permitted in process units. For primary

distribution, in selecting the power wiring method, consideration should be given to such factors as the character of the load; the soil, atmospheric, and climatic conditions; the reliability of the wiring method as related to the reliability requirements of the load, this being affected by the method by which service to standby units is provided and by the type of distribution system. An economic comparison should be made to justify more than the minimum cost installation.

From the standpoint of reliability, the four wiring methods are arranged in descending order of reliability, except that aerial cable is considered to be slightly more reliable than buried cable. All things considered, it appears that aerial cable offers the best buy. It is believed that for most cases the extra investment for aerial cable over open-wire construction can be justified. Aerial cable is favored over buried cable because aerial cable is less costly and slightly more reliable than buried cable. On the other hand, it is believed that for the general case the extra investment in cable in underground duct over aerial cable usually cannot be justified, considering the relatively small increase in reliability thus obtained.

In process units, wherever feasible, our practice has been to put the conduit underground. The wiring method specified in the National Electrical Code for class I division 2 locations has been followed for most outdoor installations in process units. Single-conductor synthetic-rubber-insulated cables have been favored in our practice, although there are some who prefer varnished-cambric lead-covered constructions. Joints and splices usually have been made above grade rather than in manholes.

In primary distribution, open-wire construction of conventional designs has been used extensively, but there is a trend away from this type of construction. Aerial cable, especially the type installed in the field by the newly developed spinner method, appears to have many advantages which make it attractive in comparison with other types of construction.

Buried cable installations have been of conventional design, except in some earlier installations splices have been made above grade. Similarly, conventional practice has been followed in underground duct runs, except that here a strongly favored practice has been to eliminate manholes, bringing the duct above-grade when a splice is required.

Three types of conductor construction have been principally used. These are

(*a*). Single-conductor, rubber or rubberlike insulated cable with a neoprene sheath.

(*b*) Single or 3-conductor varnished-cambric lead-covered cable.

(*c*) Impregnated paper-insulated lead-covered cable.

For circuits under 5,000 volts, *a* and *b* have been used, but *a* is favored for most installations. For circuits over 5,000 volts *b* and *c* have been used, but *b* is favored for most installations.

Tape-to-Page Translator; *A. E. Frost (Western Union Telegraph Company, New York, N. Y.).*

The Telegraph Company is extending reperforator switching methods to the delivery of telegrams to tie-line patrons. Some of these customers have tape teleprinters in their offices, while others prefer page machines. All business allowed to enter the main reperforator switching system is in the form of tape printer copy, unsuitable for reproduction on page teleprinters. To permit switching to page tie lines, thereby avoiding manual retransmission, the tape copy must be converted automatically into page copy. This is the purpose of the tape-to-page translator.

Page operation requires the transmission of carriage return and line feed functions. Code assignments are different for the number sign, apostrophe, comma, and period. The equals sign, per cent sign, paragraph sign, and English pound sign are tape printer characters that do not appear on the page teleprinter. The translator inserts carriage return and line feed at proper intervals and performs code conversions for all of the differences in character assignments with the exception of the pound sign. In addition, in response to the double period end-of-message signal, the translator inserts a carriage return and eight line feeds to provide well-defined separation between messages.

In switching to a page tie line, a translator is connected between the switching transmitter and the line. Each character is read by the translator and, if no conversion is required, is transmitted as received. When a character requiring conversion is read, it is discarded and the proper conversion character or characters transmitted instead. For example, on approaching the end of a line of page copy, a carriage return and line feed must be inserted. A character counter counts the characters in each line and, when it has counted a predetermined number, a circuit is established to read the next word-space character. Upon reading this word space, the translator transmits a carriage return and follows it with the transmission of a line feed. That is, a carriage return is substituted for the word space and an additional character, line feed, is transmitted before resuming normal transmission.

Most of the conversions require that more characters be transmitted than are received. Either the originating transmission must be stopped for the transmission of the added characters or, as actually is done, the input to the translator provided with storage.

The design is based on relay circuits. A rotary switch is used for two of the conversions requiring the greatest number of inserted characters. Marginal circuits were avoided and relative simplicity for the number of functions performed by the translator was obtained.

In application the tape-to-page translator is found very effective in improving speed of service and efficiency in the delivery of telegrams to page tie lines.

A Regulated Adjustable Low-Voltage D-C Supply for Electrolysis and Other Uses; *M. L. Greenough (National Bureau of Standards, Washington, D. C.).*

The use of carrier frequency amplification and rectification offers an economical and efficient approach to the design of regulated low-voltage power supplies. An instrument has been built using standard audio amplifier type of components to supply up to two amperes at five volts. Economy and reproducibility were important factors in its design. The instrument was designed for selective electroplating, where it is desired to provide exactly enough current to maintain a given potential on a reference electrode. Since the electrodes generally used in this application would be polarized by currents in excess of 200 microamperes, the control circuit of necessity must offer a high impedance to the reference electrode. By proper connection of the terminals the instrument also becomes a regulated constant-voltage or constant-current supply. The high degree of regulation incorporated results in an output impedance of less than 0.01 ohm.

The optimum carrier frequency is limited chiefly by transformer size at low frequencies and rectifier capacitance at high frequencies. In practice it has been found that 200 to 2,000 cycles is usually satisfactory. The use of as high a frequency as possible minimizes the size of filter components and reduces filter time constants, permitting greater regulator gain. It is not difficult to secure a regulator loop gain of several hundred at 2,000 cycles, for example.

A multivibrator consisting of two *6AK5* pentodes and one *6C4* triode provides a linearly controllable square-wave carrier signal. The pentodes are connected with the screen grids as anodes in the oscillating section, so that the plates generate opposite polarities of carrier signal for excitation of the push-pull power output stage. The square wave form has the advantage of requiring less filtering and permitting greater output from power tubes. The theoretical maximum efficiency of both class *A* and class *B* amplifiers is 100 per cent when handling square waves, since peak, and rms values are the same.

The principles upon which the instrument is based may be used in equipment of almost any power rating for supplying low voltage at high current, yet controllable from high-impedance circuits.

Iron-Silicon Alloys for Transformers at Power Frequencies; *G. H. Cole (Armco Steel Corporation, Middletown, Ohio).*

For more than 25 years prior to the introduction of cold-reduced oriented iron-silicon alloys, most of the core material used for 60-cycle transformers was "electrical steel" containing approximately four to five per cent silicon, hot rolled as sheet packs. Different sheets of the pack exhibited orientation textures of various types with corresponding slight variations in magnetic characteristics at different directions in the sheets. Several times during this 25-year period, new grades of core material with lower core loss guarantees were introduced. As these better grades cost more to produce it was necessary to raise the operating induction of the transformers to keep the cost of the core approximately constant but a saving in the cost of the copper coil resulted. After this series of developments had resulted in raising the operating inductions to values close to 14 kilogausses, the increases in exciting currents became prohibitively high. This problem was solved by the development and production of cold reduced coils of oriented iron-silicon alloys.

Electrical manufacturers have found ways of utilizing oriented iron-silicon alloys in designs that take advantage of the unusual characteristics of the new material. These new designs are being marketed under such

names as Hipersil type *C* cores, Spirakore, Bent-Iron, Round-Wound, and Pole Star. Other transformers of new design, but without special designation, are being made from core materials designated as Tran-Cor XX and Tran-Cor XXX. With transformer cores so designed that the magnetic flux flows parallel to the direction in which the steel was rolled, the new oriented core strip has resulted in weight reductions of distribution transformers ranging from 20 to 30 per cent.

At least one of the leading producers of oriented iron-silicon alloys anneals the strip to develop completely the magnetic characteristics but, when it is wound into a core, stresses are introduced into the metal.

An anneal at only a moderate temperature (1,350 to 1,475 degrees Fahrenheit) after this fabrication is sufficient to restore the magnetic quality. Fortunately the strip can be insulated by the steel producer so that cores can be fabricated which have negligible interlaminar loss even though the core material is reannealed after the insulation is applied. By utilizing cores wound in torroidal form (thereby avoiding the comparatively high core losses that would occur in corners of cores constructed of rectangular laminations), transformers can be built which produce quite a saving in the cost of the copper coil because of its shorter mean turn and operated at a higher induction while still meeting the core loss and exciting current requirements specified by public utilities.

A comparison of the core loss and exciting currents of core materials at several inductions of interest was presented on the slides showing the magnetic characteristics at various angles relative to the rolling direction for high-silicon hot-reduced sheet material and also for the oriented transformer core strip in which the magnetic directional effects are much more pronounced.

Crystal Orientation in Magnetic Alloys; *M. F. Littmann (Armco Steel Corporation, Middletown, Ohio).*

While the electrical conductivity of a single crystal of silicon ferrite is uniform in every direction, the ability of the same crystal to carry magnetic flux varies considerably depending on the direction of the applied magnetic force with reference to the crystallographic axes of the crystal. The data of Williams and others show that the flux carrying capacity of iron containing about three per cent silicon is 65 per cent greater in its best direction compared to its worst direction for an applied magnetizing force of ten oersteds.

The objective of utilizing the superior magnetic properties of the cube edge or [100] direction of silicon iron through crystal orientation of polycrystalline sheets first was achieved experimentally in the early 1930's. At the present time there are two commercial magnetic alloys having very high permeability in the direction of rolling because of the type of crystal orientation present. These are nominally three per cent silicon iron and 50 per cent nickel iron.

It is not possible to discern the nature or degree of crystal or grain orientation by visual examination of the macrostructure revealed by ordinary etching reagents. For example, a sheet may be highly oriented and yet consist only of very small, equiaxed grains. It is possible, however, chemically to etch material so that the facets of the pits produced are parallel to the cube faces of the component crystals. This method together with the use of the optical goniometer for measurement of reflection angles constitutes a very simple and yet fundamental way of securing information on crystal orientation in annealed magnetic alloys.

Data obtained with the optical goniometer are most readily understood in the form of stereographic projections of normals to the cube faces of the crystals. The relation of crystal orientation to the permeability in various directions within a given specimen can be shown in the form of polar graphs.

Hot rolled iron silicon sheets tend to have somewhat higher permeability at an angle of about 38 degrees from the rolling direction whereas the "oriented" cold reduced sheets exhibited very high permeability in the rolling direction but comparatively low permeability at all other directions, the minimum occurring at an angle of 55 degrees to the rolling direction. In the case of 50 per cent nickel iron, the permeability is very high both in the rolling direction and at 90 degrees or transverse to the rolling direction.

Iron-Cobalt Alloys for High Induction Applications; *J. K. Stanley (Westinghouse Research Laboratories, East Pittsburgh, Pa.).*

An investigation of the d-c and a-c properties of iron-cobalt alloys in the range of 25 to 50 per cent cobalt containing one per cent vanadium or 0.7 per cent chromium shows that the saturation induction is highest around 24,000 ($4\pi I_s$) for alloys containing 35 to 50 per cent cobalt. The 50 per cent cobalt alloys have high permeability at $H=10$ oersteds. Permeabilities over 2,000 and coercive forces as low as 0.24 oersted were obtained by annealing from 800 to 900 degrees centigrade in dry hydrogen.

The high saturation and good permeability at low magnetizing fields make the iron-cobalt alloys containing 35 to 50 per cent cobalt useful for applications where space or weight are at a premium and where cost is secondary. If electric machinery is designed with iron-cobalt alloys in mind weight savings up to 20 per cent can be achieved.

Increase in impurities such as carbon and oxygen harms the magnetic quality, decreasing permeability and increasing coercive force. A fine grain size is harmful to good quality. By increasing the grain size the permeability is improved and the losses are lowered. Iron-cobalt alloys cannot be annealed at temperatures above 925 degrees to promote grain growth and to facilitate the removal of impurities because the phase transformation occurs around 950 degrees centigrade.

The saturation magnetostriction of the iron-cobalt alloys in the range of good saturation is higher than for any other ferromagnetic material. Values up to 11×10^{-5} have been obtained. The presence of carbon appears to lower the magnetostriction.

Order-disorder phenomena appear to play an important role in this system with respect to ductility, saturation magnetostriction, and electric resistivity.

The processing of iron-cobalt alloys depends to a great extent upon the ability of the glass-brittle alloys to become ductile when quenched from a temperature range of 750–900 degrees centigrade. The quenching apparently retains the disordered state allowing the quenched material to be cold rolled to any thickness. When the cold worked alloy is annealed and slowly cooled for optimum magnetic quality the disordered structure is converted to an ordered one and the alloy becomes brittle again.

The development of a high degree or order also results in increased magnetostriction and decreased electric resistivity.

Short-Circuit Currents and Recovery Voltages on Rural Distribution Systems; *W. H. Eason, J. W. Kalb, I. B. Johnson (General Electric Company, Schenectady, N. Y.), H. A. Peterson (University of Wisconsin, Madison, Wis.).*

Field tests were made on a 7,200/12,470Y-volt multigrounded rural distribution system to check fault current calculations and to investigate transient recovery voltages experienced as a consequence of clearing fault currents. Tests also were made using a miniature circuit representation of a rural distribution system in order to investigate the effect of variations in circuit conditions incident to the fault. The use of the miniature system or transient analyzer made possible a determination of the order of magnitude of crest voltages and rates of rise that may be expected under most severe conditions. The work is expected to be of considerable value in the preparation of standards for the testing of such devices as expulsion lightning arresters and distribution fuse cutouts. In so far as the authors are aware, this is the first published information on transient recovery voltage tests on rural distribution systems and the correlation therewith of transient analyzer results.

The studies showed that the transient recovery voltages experienced are effected in varying degrees by numerous factors. Some of the more important factors are

(*a*). The length of line remaining connected to the substation after fault interruption.

(*b*). The distance between the substation and the fault.

(*c*). The X/R ratio of the line between substation and fault.

(*d*). Arc voltage characteristics of the fault clearing device.

(*e*). Complexity of system network.

(*f*). Damping due to system load connected after fault interruption.

(*g*). Kilovolt-ampere capacity of substation transformer bank.

(*h*). Lumped capacitance between line and ground in substation bus structure or power factor capacitors.

During field tests, the highest crest voltage measured was 1.33 times normal crest voltage and occurred when a fault about 16 miles from the substation was cleared by a line sectionalizing recloser. This value is somewhat higher than most of those obtained in the field tests and appeared to be due primarily to an unusually rapid rise in arc voltage in the sectionalizing device just prior to clearing.

The most rapid rate of rise of recovery voltage recorded in the investigation occurred during field tests for a fault at the substation which was cleared by the main substation sectionalizing fuse leaving no connected line. It rose to 0.9 normal crest voltage in 22 microseconds. In this case, the crest recovery voltage was only 0.94 times normal.

When more severe circuit conditions were

investigated using the transient analyzer, crest recovery voltages of the order of 1.75 times normal were obtained. These values occurred with six miles of unbranched line connected after the fault, and 50 kva of transformer capacity. As the kilovolt-amperes were increased to 2,000, with other factors constant, the crest voltage dropped to 1.28 but the rate of voltage rise increased so that 0.9 normal voltage was attained in 80 microseconds as compared with 280 microseconds with a 50-kva bank.

Short-circuit currents recorded in field tests were in excellent agreement with those calculated by means of simplified methods using special graph paper and template.

Overcurrent Investigation on a Rural Distribution System; *D. R. Edge, (Graybar Electric Company, Chicago, Ill.), W. C. McKinley (Central Electrical Cooperative, Parkers Landing, Pa.), G. F. Lincks, J. H. Leh (General Electric Company, Pittsfield, Mass.).*

Good service continuity with the least possible outlay is a major problem on every rural distribution system. Sectionalizing the primary line is accepted practice today to improve continuity. The problem is to formulate numerically the benefits obtainable with different types of equipment and to find better protective methods.

An overcurrent investigation was conducted during 1944, 1945, 1946, and 1947, with these objectives in mind, using the 7,200/12,470Y-volt 4-wire multigrounded Y rural distribution system of the Central Electrical Cooperative of Parkers Landing, Pa. The system serves an area of 40 by 60 miles. In 1944 more than 4,000 consumers were fed through approximately 3,000 transformers on 1,015 miles of primary line ($87\frac{1}{2}$ per cent single-phase line-to-neutral construction) divided into four main feeders; power is supplied by two 900-kva transformer banks.

A study of the system requirements showed the need for coordinated overlapping operation of recloser and fuses on the entire system. These should be arranged so the recloser clears all nonpresistent faults with only a momentary outage but in the case of a persistent fault would cause a fuse to isolate only a small faulted section of the line. In order adequately to sectionalize the lines, the recloser has to be co-ordinated with sectionalizing fuses between reclosers, branch fuses, subbranch fuses, and transformer fuses (of both external and internal types), all connected in series for sequential operation.

Actual co-ordination studies were made on this rural system assuming the use of all types of reclosers co-ordinated with fuses for overlapping protection. These studies showed that the recloser which opened twice instantaneously, then locked closed until the proper fuse blew, and then reset automatically, was the only one that would meet all of the system requirements. As no commercial design was available in 1944, the existing General Electric *FP-119* reclosers on this rural system were modified to provide the lock-closed function.

Data were obtained from the reports of service crews and from automatic General Electric *PM-13* oscillographs connected on two of the four main feeders.

In analyzing the data it was found that treating the four 3-phase feeders as 12-single-phase circuits provided the most accurate information on the operation. Also, it indicated that such treatment of a 3-phase circuit having predominately single-phase loads would aid in obtaining the best results in applying protective equipment.

The frequency of occurrence of different causes of faults and the exposure, measured in the number of faults per mile of primary line, was shown to be similar to other published data. This indicated that the results obtained in this investigation should be of value to all operators of rural systems.

Single-phase circuits of 40 to 60 miles in length showed from 3.1 to 13.0 hours outage per consumer per year, even with the coordinated overlapping fuse-lock-closed recloser protection. This is higher than can be tolerated on rural systems. It appeared from data on a 25-mile-long feeder that if it had been equipped with the improved fuse-recloser protection a desirable standard of two hours outage per consumer per year might be obtained.

The fuses and lock-closed reclosers coordinated for overlapping operation showed very substantial reductions in hours outage per consumer per mile of line per year varying from 70 to 90 per cent. Also, the savings in restoration expense obtained was 32.8 per cent in man-hours and 26.8 per cent in mileage traveled. This 28.5 per cent saving in cost will justify an investment in reclosers and fuse cutouts of $3,400 with an annual charge of 15 per cent or $12,750 with a four per cent annual charge. This would either carry one-third of the $10,500 cost for the protective equipment required on the system investigated or woud result in a net profit of $90 per year over the carrying charge, depending on the financing.

The oscillograph measurements of fault currents were checked against the calculated values indicating that the assumption of 40 ohms for fault resistance for calculating minimum fault currents was more than ample and might have been 30 ohms.

Inrush currents following prolonged outages, measured on the two feeders on which the oscillographs were located, never exceeded 2.5 to 3 times the normal current. Thus they were not troublesome in restoring service. However, trouble in reclosing the circuit on another feeder (without the oscillographs to record the currents) was solved by shunting the recloser with a fuse. The lock-closed recloser performs a similar function automatically if an impulse current should lock it closed. Thus a system protected by fuses and lock-closed reclosers should be free from inrush currents preventing service restoration following prolonged outages.

Differential Leakage of the Different Patterns of a Fractional Slot Winding; *M. M. Liwschitz (Polytechnic Institute of Brooklyn, Brooklyn, N. Y.).*

When the conditions for balance are satisfied, a fractional-slot lap winding can be laid out in many different patterns, all of which are balanced. The usual pattern is that for maximum distribution factor of the main wave. If this pattern is called the "basic," all other patterns can be derived from this one by cyclic shifts of coils from one phase to the other within the same repeatable group. The distribution factor of the main wave of the derived patterns, that is, of the patterns with cyclic shift of coils, is always smaller than that of the basic layout. As regards the distribution factors of the harmonics of the derived patterns, some are smaller and some larger than those of the basic pattern.

It is assumed generally that the patterns with cyclic shift of coils have a smaller differential leakage than the basic pattern. This assumption is not correct and the use of patterns with cyclic shift of coils is justified only when, with regard to noise or telephone interference, it becomes necessary to reduce one or several electromotive force or magnetomotive force harmonics.

The differential leakage of a 3-phase fractional-slot winding is given by the equation

$$x_d = \frac{4}{\pi^2} m + N_{ph}^2 \frac{\tau l_e}{pgk_ck_s} 10^{-7} \times C \text{ ohms/phase} \qquad (1)$$

with

$$C = \frac{\beta^2}{4} \sum_{\nu \neq \beta/2} \left(\frac{k_{dpn'}}{\nu} \right)^2 \quad \nu = 1, 2, 4, 5, 7 \ldots \qquad (2)$$

when β is an even number and

$$C = \beta^2 \sum_{\nu \neq \beta} \left(\frac{k_{dpn'}}{\nu} \right)^2 \quad \nu = 1, 5, 7, 11 \ldots \qquad (3)$$

when β is an odd number. The meaning of the symbols is

m = number of phases
f = line frequency
N_{ph} = number of turns per phase
τ = pole pitch
l_e = effective core length
p = number of pole pairs
g = air gap
k_c = Carter factor
k_s = saturation factor
β = denominator of the fraction which fixes the number of slots per pole per phase
$k_{dpn'}$ = distribution factor times pitch factor of the n'-th harmonic
n' = order of the harmonic with respect to a fundamental, the wave length of which is equal to $2p\tau$

The cyclic shift of coils does not introduce new harmonics ν, nor does it change the pitch factors of the winding. It changes only the distribution factors $k_{dn'}$. Therefore, for a comparison of the differential leakage of the different patterns, it is sufficient to compare their magnitudes of C.

As an example, a 3-phase winding with $2\frac{3}{8}$ slots per pole per phase will be considered. The coil grouping of phase A for the basic layout of this winding is, in 8 poles,

3 2 2 2 2 2 3 3

Calculations were made for the basic layout and for three cyclic shifts of coils which yield the following coil groupings for phase A in 8 poles:

3	2	2	3	2	2	2	3	cyclic shift 1
3	2	3	2	2	2	3	2	cyclic shift 2
3	2	2	2	2	3	2	3	cyclic shift 3

The calculation shows that any cyclic shift of coils increases the distribution factors of the subharmonics while some of the distribution factors of the harmonics of higher order than the main wave are smaller, and others larger than those of the basic layout.

Table I shows the quantity $C = 16 \sum_{\nu \neq 4} \left(\frac{k_{dpn}'}{\nu} \right)^2$, that is, the relative differential leakage, for the four different layout patterns at three different ratios of coil pitch W to pole pitch τ. It can be seen from this table that, with the subharmonics neglected, the differential leakage of the patterns with cyclic shift of coils is somewhat smaller than that of the basic layout and that, with the subharmonics taken into account, the differential leakage of the patterns with cyclic shift of coils is much larger than that of the basic layout. It is true that the harmonics of low order and especially the subharmonics, are more damped by a squirrel cage rotor or by eddy currents than the harmonics of higher order. However, no gain with respect to the differential leakage can be expected from the cyclic shift of coils for the winding considered.

The investigation of other numbers of slots per pole per phase shows results similar to those of the example, thus confirming that normally the basic layout should be used and the cyclic shift of coils should be applied only when one or several harmonics are to be reduced.

Table I. Relative Differential Leakage of a 3-Phase Winding With $2^3/_8$ Slots Per Pole Per Phase for Different Layout Patterns

W/τ	Basic Layout	Cyclic Shift 1	Cyclic Shift 2	Cyclic Shift 3	
0.983	0.0218	0.0176	0.0182	0.0176	Without subharmonics
0.842	0.0186	0.0165	0.0170	0.0176	
0.701	0.0175	0.0155	0.0172	0.0172	
0.983	0.0263	0.0458	0.0320	0.0286	With subharmonics
0.842	0.0224	0.0374	0.0278	0.0259	
0.701	0.0199	0.0307	0.0244	0.0241	

An Octal System Automatic Computer; *J. P. Eckert, Jr., J. W. Mauchly, J. R. Weiner (Eckert-Mauchly Computer Corporation, Philadelphia, Pa.).*

The Eckert-Mauchly Computer Corporation has completed the design and construction of a new all-electronic automatic computer. It was designed primarily for the solution of engineering problems. The basic computer contains 48 removable chassis and occupies a space 6 feet by 6 feet by 2 feet. A separate cabinet contains the power supply and another contains both the input-output circuits and a magnetic tape recording system with which is associated a special keyboard and electrically operated typewriter.

The BINAC* uses a multichannel mercury delay-line memory. Through one mercury pool there are 16 paths, in each of which can be stored 32 10-digit octal numbers with their signs. The over-all capacity of this memory is, therefore, 512 words. The fundamental pulse rate of the whole system is 4 megacycles. This high pulse rate has required some new circuit designs which have not been used in any previous computer.

The BINAC can perform all the basic arithmetic operations. Its progress consists of numerical coded instructions which are stored in the mercury memory and used sequentially. It is possible to make use of subroutines of instructions repeatedly in the course of a main sequence.

The input-output system does not make use of the magnetic tape directly. Operation of the special octal keyboard delivers sets of binary digits into a one-word memory, which when filled, transfers its contents to the proper location in the main mercury memory. Similarly, information within the main memory first is transferred to the one-word memory and then directly to the typewriter. The main use of the magnetic tape is as an auxiliary memory. The information within the mercury memory can be put upon tape or information stored on the tape can be transferred into the main memory.

The BINAC marks a major step in the development of electronic computing instruments. It is smaller in size, yet has much of the flexibility contained in the larger computers now contemplated. The entire computer, including the input-output circuits, uses less than 800 vacuum tubes, all of standard type.

* Trade-mark, Eckert-Mauchly Computer Corporation.

EDVAC Test Instrumentation; *R. L. Snyder (University of Pennsylvania, Philadelphia, Pa.).*

The EDVAC is a large-scale electronic digital computer which now is undergoing the tests necessary to place it in operation. This machine computes in the binary number system with numbers which consist of 43 digits and a sign. A digit is represented by a pulse if it is one and by a space if it is zero. The digits are distributed in time and follow one another at one microsecond intervals, all of them passing through the same channels. Instructions for the computations also are conveyed in the same manner and both types of signals are called words. Information from the outside is derived from magnetized wire driven at a relatively low speed and from manual switches. In addition to the digit pulses, switching signals are employed whose duration is much longer and which open and close electronic gates. Each word is accompanied by four additional one-microsecond blank spaces to provide time for the switches to set up so that the duration of a signal train is 48 microseconds, a period called a minor cycle. The switching signals are usually a minor cycle in duration.

In order to understand what is involved in the testing procedure of such a machine and to indicate the instrumentation required for these tests, it is desirable to enumerate the major components and indicate their functions: *Reader-recorder* is the mechanism that drives and controls the magnetized wire records of input and output information in accordance with instructions stored in the internal memory and the control. *Control* is the unit through which all manual operations are communicated to the machine and the progress of the computations is observed. *Memory* consists of a group of 128 mercury acoustic delay systems, each capable of storing eight words and making the word available in less than 384 microseconds. *Dispatcher* is the element which automatically directs all of the operations of the machine, securing orders and numbers from the memory and control, and executing the operations on the numbers indicated by the orders. *Computer* is the arithmetic organ of the machine in which all algebraic operations are performed under the direction of the dispatcher. *Timer* is the unit which generates the EDVAC'S synchronizing signals. *Switchboard and power supply*—the switchboard distributes power in the machine and the power supply provides regulated direct current for plate supplies. *Input-output system*—this equipment, which was designed by the National Bureau of Standards and is external to the EDVAC proper, is used to place input information on magnetized wire from a keyboard, and to print the results from a magnetic record of the computer output. The test equipment required by this program consists of several wide-band oscilloscopes, high-impedance voltmeters, ohmmeters, and four specialized instruments enumerated in the following. *Artificial word generator* is a generator to provide signal trains similar to EDVAC signals whose composition of pulses and spaces can be changed by switches. *Simulated gate* is a combination of flip-flops which can develop signals similar to the switching signals of the computer. *Synchronizing counter* is a counting frequency divider which reduces the pulse repetition rate of the timer to a value suitable for triggering the sweep of an oscilloscope. *Auxiliary clock pulse generator* is a portable pulse generator similar to the clock pulse source in the timer.

In carrying out the test program the power supply and timer were activated first because all the other units require their outputs. The memory was set up next because it determines the frequency at which the timer will operate. The control and part of the dispatcher along with the computer followed, to provide a means of manually placing words in the memory and subsequently performing automatic computations. The reader-recorder and input-output equipment are the last units to be tested because they are not needed in any of the other tests.

At present the progress has advanced to the point where successful operation seems assured. The choice of an acoustic memory, whose reliability has been subject to some doubt, has been vindicated by prolonged successful operation. Several computing circuits have caused surprisingly little trouble in operation and the logic of the original design appears to be sound. There now remains only routine tests and general cleanup to complete this computer project.

Thin-Gauge Iron-Silicon Alloys for High-Frequency Applications; *D. C. Dieterly (ARMCO Steel Corporation, Middletown, Ohio).*

Wartime demands for magnetic materials to operate efficiently at high frequencies were met quickly by the quantity production of iron-silicon alloys in gauges as thin as 0.002 inch. Since the war, further improvements in these thin-gauge electrical steels have resulted in better magnetic quality along with improved surface resistance and space factor. Today these materials, available in an adequate choice of thicknesses down to 0.001 inch, combine high initial permeability, very low losses, and high saturation induction.

Now, for the first time, it is possible to offer to designers of high-frequency components wide-range magnetic data on these materials at the frequencies and inductions at which the materials are used most effectively. Such data are available as curves covering

completely the range of inductions from ten gausses to ten kilogausses, and for frequencies from 60 cycles to 100 kc. Of particular interest are the properties in this range, of 0.002 inch Armco thin-gauge electrical steel, a three per cent silicon-iron alloy which has characteristics especially suited to operation in the carrier frequency range or at high frequencies in the audio range. Actual test data show the effective permeability of this versatile material to be greater than 1,000, at most inductions, even at frequencies of 100 kc. At frequencies of 20 to 30 kc, there is so little skin effect that the permeability characteristics are essentially the same as for very low frequencies.

D-c tests show that this 0.002 inch thick material has an initial permeability greater than 1,500, and a maximum permeability of about 16,000 which occurs at approximately 10 kilogausses. The hysteresis loss at an induction of 10 kilogausses is only about 900 ergs per cubic centimeter per cycle (5.35 milliwatts per pound per cycle), and at 15 kilogausses is only 2,150 ergs per cubic centimeter per cycle (12.8 milliwatts per pound per cycle). The hysteresis loop at moderate inductions is quite steep, making available a large change of flux for a small change in magnetizing force.

The preparation of such wide-range magnetic data was made possible by utilizing special testing techniques which are not as yet in general use for testing magnetic materials. All the tests were made on Epstein strips $1^3/_{16}$ inches wide and 12 inches long. Only a one-fourth-pound sample was required for an accurate test. Core loss tests at frequencies from 60 cycles to about 10 kc were made by the conventional wattmeter method of American Society for Testing Materials designation *A-34-46*. An astatic reflecting type wattmeter of special design giving very high sensitivity with low phase-angle error was employed for these lower-frequency tests. At frequencies above 3,000 cycles (and up to 100 kc or higher), a resonance bridge test method was used. An Epstein test frame, specially designed for operation at these very high frequencies, and the use of double-lap joints in the test sample, made possible a high degree of accuracy in the tests.

The electrical steels on which these data were obtained have many attractive features other than their excellent magnetic properties. They are fully annealed by the producer and supplied in long coils of continuous strip suitable for rapid fabrication of wound cores. The strip is coated at the mill with an extremely thin film of a special insulating material known as Carlite which provides adequate insulation, yet permits space factors of better than 85 per cent in wound cores of 0.002 inch thick material. These thin-gauge materials represent another forward step by the magnetic materials producer to supply material necessary for the construction of better high-frequency components, in a form which fits into the scheme of modern production methods.

Materials for High-Frequency Applications—Magnetic Ferrites; *Frank G. Brockman* (*Philips Laboratories, Inc., Irvington-on-Hudson, N. Y.*).

As the result of research conducted in the Philips Laboratories in Eindhoven, Holland, by Snoek, Verwey, and their coworkers, a series of nonmetallic magnetic materials have been developed.

The ferrite materials developed by the Philips Company are sold under the trademark FERROXCUBE.

These materials are chemical compounds called ferrites and the general chemical formula for them is $M+^2[Fe_2O_4]$. In this development, the ferrites of interest are those which have a cubic crystalline structure like the mineral "spinel." The ferrites with the spinel structure are chiefly Cu, Mg, Mn, Ni, Fe(ous), and Zn ferrites. It is known that two varieties of the spinel structure exist which differ in the distribution of the metallic ions over the lattice. These varieties are called "normal" spinel and "inverse" spinel lattices. By careful crystallographic studies it has been possible to show that some of the ferrites mentioned are inverse and some normal. This has been correlated with the ferromagnetic behavior; normal spinel ferrites are not ferromagnetic while inverse spinel ferrites are ferromagnetic. It has been found that when homogeneous mixed crystals of nonferromagnetic and ferromagnetic ferrites are prepared, the magnetic Curie temperature is lowered. This fact has been utilized to reduce the magnetic anisotropy since it is known that if a ferromagnetic material is used below, but still near to the Curie temperature, the anisotropy is less than observed at temperatures much below the Curie point.

On the principle that a maximum value of the initial permeability is obtained when both the anisotropy and the magnetostriction are small, high permeability ferrites have been developed. The anisotropy is reduced as described, while the magnetostriction is reduced by preparing homogeneous mixed crystals of ferrites with magnetostriction constants of opposite sign.

The outstanding feature of these materials is their low electric conductivity. This low conductivity is the consequence of chemical combination in the ferrites, for the electrons are bound in these compounds by valence forces. The electric resistivities can be of the order of 10^7 to 10^{11} times that of iron. This is reflected in low eddy current losses.

FERROXCUBE materials are finding numerous applications especially in communications components. Applications in which large values of induction are required (as, for instance, in power transformers) will not be numerous. This is so because these materials saturate at about 3,000 gauss.

At Philips Laboratories, Inc., Irvington-on-Hudson, N. Y., it has been discovered that some of the FERROXCUBES have remarkably high dielectric constants. At high frequencies this property has a decided influence upon the magnetic properties.

Magnetic Properties at High Operating Temperatures; *M. L. Manning* (*Kuhlman Electric Company, Bay City, Mich.*).

This preliminary study originated by the manufacture of dry-type distribution transformers using silicone insulating materials known as class *H* and cold rolled oriented silicone steel cores. Silicone insulation will withstand continuous temperatures of 200–250 degrees centigrade which opens new pathways in transformer design. Weight and space reduction up to 40 per cent over old designs is accomplished by combination of these materials. Former maximum temperature for insulation such as class *B* was 130 degrees centigrade. The question arises as to the effect of 250 degrees centigrade continuous temperature upon the magnetic properties of steel.

The topic was assigned to the writer by the subcommittee on magnetics only a few weeks ago. Comprehensive and complete studies on all phases of the problem are not possible on such short notice. It is hoped that the preliminary data presented in this the first paper will stimulate much basic research on magnetic properties of oriented steel at elevated temperatures of 250 degrees centigrade and higher.

Preliminary studies for relatively few samples reveal that for Epstein samples the core loss decreased slightly at 250 degrees centigrade; for transformer core structures the core loss (watts per pound) increased to 12 per cent at 250–300 degrees centigrade temperatures.

For the few sample tests on magnetic structures considered, the data presented should be of interest to the transformer design engineer and of general interest to designers of electric apparatus. Magnetic characteristics of Armco Tran-Cor XX and Tran-Cor XXX were studied over a range of operating temperatures from 25 degrees centigrade to 300 degrees centigrade using Epstein and transformer core structures. Most studies on core materials have been made in the past on Epstein samples. Practically, the electrical designer is interested in magnetic structures similar to those of the completed electric machine or device. Consequently comparative data for core steel properties obtained in this manner are of the most value to the designer.

The following comments may be made:

1. For relatively few transformer core structures subjected to 250 degrees centigrade for 11 days and to 300 degrees centigrade for 63 days at 17 kilogausses induction density, the increase in core loss in watts per pound was 11.2 per cent at room temperature compared with original core loss at room temperature.

2. For a 4-inch-inner-diameter 11/16-inch-thick 6-inch-width core structure, the core loss in watts per pound measured an increase of 5 per cent at 25 degrees centigrade after being subjected to 250 degrees centigrade for 13 days at 17.05 kilogausses induction density compared with original 25 degrees centigrade measurement.

3. Epstein tests on few samples (American Society for Testing Materials *A34*) reveal a core loss watts per pound decrease of 15 per cent to 18 per cent after being subjected to 250 degrees centigrade continuous temperature.

4. Before conclusive arguments can be advanced about increased core loss in actual core structures at 250 degrees centigrade temperature many transformer units must be tested.

5. It is hoped that this preliminary study of the problem will open the pathway for thoughtful research.

Structure and Properties of the Permanent Magnet Alloys; *Alfred H. Geisler* (*General Electric Research Laboratory, The Knolls, Schenectady, N. Y.*).

The properties of the older carbon and alloy steels depend upon the eutectoid reaction in the Fe-C system and the quench hardening of these alloys by the martensite reaction. The coercive force of these alloys is limited to a maximum under 300 oersteds. Many of the alloys including Comol, Cunife, Cunico, the Alnicos, Silmanal, and possibly Vectolite are of the precipitation type. The reaction in the various alnicos originates in a miscibility gap in the ferrite field of the

Fe-Ni-Al system. The third reaction, superlattice formation, is represented by alloys such as Vicalloy, Co-Pt, and Fe-Pt. Both precipitation and superlattice formation provide alloys with coercive forces up to 6,000 oersteds.

The changes in properties during the reactions in solid solution depend upon two factors: the effects of composition, structure, and quantity of the ferromagnetic phase, and the effects of transient interaction strains between the matrix and new phase and their relieval during the reaction. Mainly the former control the degree of ferromagnetism as indicated by induction at saturation or residual induction. The latter control coercive force and energy product in so far as it depends on coercive force. The crystal structure and strains during the reactions have been determined for a number of alloys. Plate-like particles of the reaction product form bearing discrete crystallographic relations to the matrix phase. At first these particles retain the atomic distribution and spacing of the matrix on the plane of the lateral dimensions of the plate. This transition structure can be considered as the final phase strained homogeneously to match the matrix. The strain through the thickness of the plates is different from those in the plane. Thus, anisotropy of both shape and strain exists. The latter is held responsible for coercivity since these homogenous strains would be expected to resist magnetostriction thus providing a resistance to magnetization and demagnetization. Homogenous strain as indicated by crystallographic misfit between phases in their normal structure is directly proportional to coercive force in comparable alloys. A physical representation of the origin of permanent magnetism was presented and used to explain anisotropy of the certain permanent magnet alloys.

Low-Voltage A-C Testing; *I. G. Easton (General Radio Company, New York, N. Y.).*

It can be shown that a correlation exists between the dissipation factor of an insulating material and its moisture content. Changes of this quantity are used successfully to check on the condition of bushings and similar insulating structures.

Both dielectric constant and dissipation factor of insulating materials change in a complicated manner with temperature, humidity, and frequency. In practically every important case the variation is such that at a given frequency near the power range it will be found that dissipation factor increases with increase in moisture or temperature. As the voltage applied to the material is varied, however, it is found that no significant changes occur until the insulation is stressed to the point where corona occurs. Consequently, essentially the same information can be obtained by a low-voltage measurement as by a measurement at fairly high voltage.

From the point of view of designing a test set, low voltage is attractive because of the lower cost, weight, and size. On the other hand, sufficient voltage must be used so that the advantages are not sacrificed by the high detector sensitivity needed at very low voltages. An examination of the economic factors involved suggests that for a bridge type of measurement the optimum voltage from the point of view of economy of price, size, and weight lies in the range 100 to 500 volts.

The most economical frequency to use is 60 cycles (or more generally the power-line frequency) because of its ready availability. Measurements at low voltage and power line frequency are difficult, however, because of the interfering voltages induced in the insulators under test. Several methods are available for eliminating or reducing the effects of the interference. Of these, the most attractive, from the economic point of view, is to change the frequency of test. The necessary discrimination between the interfering voltage and the test voltage can be obtained rather readily if a test frequency of 120 cycles is used. At this frequency the variation of dissipation factor with moisture is essentially the same as at 60 cycles.

Therefore, it is concluded that a null balance circuit operating at 120 cycles with a test potential in the order of 500 volts would represent the most economical and convenient approach to the problem of measuring the dissipation factor of insulation in the field.

Common Circuit Arrangements for A-C Tests on Dielectrics in the Field; *E. D. Doyle, W. G. Amey (Leeds and Northrup Company, Philadelphia, Pa.).*

A-c testing of dielectrics in the field introduces problems which usually have no counterpart in the laboratory. These problems generally involve one or more of the following:

1. Provision of a suitable source of test voltage.
2. Provision of suitable circuit arrangements for testing a specimen which has one terminal grounded.
3. Provision of arrangements for guarding against disturbances from other nearby high-voltage high-powered circuits.
4. Provision for guarding against stray leakage from the test source itself.

Without regard to the particular instrumentalities employed, the various common methods of connecting the test circuit elements can be compared qualitatively with respect to the foregoing provisions. Such summarized qualitative comparison is a relatively simple basis for quantitative evaluation where circuit parameters are known.

Intermediate-Voltage A-C Testing of Dielectrics in the Field; *I. W. Gross (American Gas and Electric Service Corporation, New York, N. Y.).*

The increased rate of failures of high-voltage bushings in service about 20 years ago (1929) resulted in a search by the American Gas and Electric Company for practical and reliable test equipment capable of determining the conditions of the insulation of high-voltage equipment before it failed. Preliminary tests at that time on 4,000 bushings in circuit breakers indicated the potentialities of the 60-cycle 10-kv power factor field test set.

Its use in the field was extended progressively to transformer bushings and windings, cables, cable potheads, oil, bus and switch insulators, lightning arresters, insulation within apparatus, and wood including hot line tools. At the present time ten field test sets are in use on the system where the test work first was initiated 20 years ago.

Standard power factor limits and other criteria such as watts loss and current now have been set up for practically all equipment tested in the field. These standards are based on the accumulated results of thousands of field tests on all kinds of equipment of all ages. Field power factor testing of most equipment of 22-kv rating and above has now become standard practice by the company reporting, much the same as routine testing of watt-hour meters or relays.

The test set, in routine testing, is mounted in a light car of commercial design, specially fitted inside to house the test equipment, and with arrangements and fittings for convenience of the field test engineers.

The objectives sought are reported as having been fully realized. They are

1. The reduction to a practical limit of failures in high-voltage apparatus.
2. The development of a practical field test set and method of determining the condition of high-voltage insulation.
3. The improvement of continuity and reliability o electrical service.
4. The improvement of over-all economy of high-voltage systems by detecting faulty equipment, and replacing or servicing it before failures occur.

Testing of Insulation at High-Voltage Alternating Current; *A. L. Brownlee (Commonwealth Edison Company, Chicago, Ill.).*

Insulation safe for use in a power system must be able to withstand alternating voltage well above that at which it normally operates. Up to operating voltage the insulation should show no signs of distress.

Power factor (or angle of phase defect) is used to determine the condition of the insulation and its stability under a-c stress. The numerical value of power factor, its constancy at a constant voltage, or its change with changing voltage give indications of condition and stability of an insulation.

The ideal power factor versus voltage curve is a straight horizontal line, at least to operating voltage. Any deviation from this form is undesirable. The deviations that occur may be either increases or decreases in power factor with increasing voltage, depending on the mechanism that is involved.

Ionization somewhere in the insulation as in voids is a cause of ascending power factor versus voltage curves. The typical shape for this condition is an upturn from the horizontal. The knee in the curve indicates the voltage at which corona sets in and that point should lie above operating voltage. Deviations in the power factor versus voltage curves also are caused by carbonization, moisture, and other contamination. If the resistance of a portion of the insulation is reduced by any one of these causes, the resulting circuit consists of a capacitance in series with a parallel combination of resistance and capacitance. The resistance of the contaminated or deteriorated portion decreases with increasing voltage. With decreasing resistance the power factor of such a circuit increases first, goes through a maximum, and then decreases. The power factor versus voltage curves, therefore, either may be ascending, decending, or may be ascending at the lower voltages and descending at the higher voltages.

Electrical Hazards to Farm Stock; *W. B. Buchanan (Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada).*

The subject of this paper evolved from the fact that a large number of cattle had been electrocuted while standing in their stalls and elsewhere on stock farms and such experiences were widespread. Inspectors and others were much concerned and asked that a fact-finding study be made.

Some data were derived giving, in quantitive terms, the limit of tolerance of current and voltage as an approximate guide as to what might be tolerated in exposed locations. For example, animals have been killed with 32 volts, violent commotion has been set up in a stable with less than 20 volts between water bowls or steel stanchions and the floor where the animals stood. This does not mean that lower voltages are safe but that the values given have proved fatal or intolerable.

Earth currents alone cannot be relied upon to clear the circuit by blowing fuses, and so forth, but currents and voltages of lethal values can be set up and sustained in unauthorized and remote places. Present regulations for various codes call for bonding metallic enclosures by some means back to the secondary neutral but many of the older installations have not been brought up to date.

Where the practice is followed of connecting the primary and secondary neutral conductor together, this automatically would put all such metallic enclosures of electric circuits at the potential of the primary neutral. A more definite knowledge of the conditions prevailing on distribution lines was needed and studies on a large scale have been carried out.

The possible consequences of carrying primary neutral voltages through to the steel and water bowls in the stalls led to the suggestion that the latter should be isolated, if at all possible, from any part of the electric circuit. Considerable factual data tend to discredit the value of water piping in stables, either as current carriers or for grounding purposes, and dependence thereon can be very hazardous. Hence, isolation was recommended for those extensions which otherwise would be free from possible contact with any enclosures of electric circuits.

Whatever may be done, initially, to provide an installation free from hazard, various types of deterioration noted, and others, point to the need of periodic reinspection and test by inspectors specially trained in this class of work. This falls at present within the authority and control of the owner in most, if not all, cases and an intensive educational program may be necessary to enlist the co-operation of all concerned to keep hazards to a minimum.

If hazards are to be avoided there is need for more reliable test data in individual cases rather than relying on convenient assumptions.

Rural Neutral Potentials; *J. H. Waghorne (Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada).*

The Hydro-Electric Power Commission of Ontario owns and operates 27,000 miles of rural distribution lines serving 223,000 consumers in areas where no common water supply is available for grounding purposes. A multigrounded, common primary and secondary, neutral system with grounds at each transformer and on each consumer's premises is used for 92 per cent of this mileage.

The use of driven rods to protect metallic enclosures of electric wiring and equipment in case of insulation failure has not been entirely satisfactory. In most cases it is not possible to obtain sufficiently low ground resistance with a driven rod to clear the secondary fuses in case of a fault so the condition is sustained. Through connections to steel stanchions via water systems and milking machines, such fault conditions can prove and have proved fatal to farm stock.

Connection of metallic enclosures to the neutral ensures the clearing of secondary insulation failure but simultaneously subjects the enclosures to any voltages on the neutral due to load or faults on the primary system. The commission has conducted an extensive survey to determine the hazard from primary neutral potentials under four conditions: normal operation, unusual loads, primary faults, lightning surges.

Under normal operation multigrounded neutral potentials can be maintained at safe values without undue expense.

When an unusual load condition exists neutral potentials should be checked to make sure no dangerous voltage exists.

Primary phase-to-neutral faults can produce serious voltages on the neutral but their infrequent occurrence and short duration reduce the hazard to some small undetermined value. Satisfactory operation for 17 years with a small percentage of the consumers' metallic enclosures connected to the common neutral has provided some confidence that the hazard involved is very slight.

Due to flashing over of insulation the largest lightning surges will appear on metallic enclosures even if they are not connected to the neutral so such a connection does not increase this hazard appreciably.

In 1947 wiring regulations in rural areas were changed regarding two major points. Metallic enclosures are to be connected to the neutral at the distribution box and to a driven ground and the use of nonmetallic sheathed cable and outlets of insulating materials is to be preferred, particularly in stables.

Protective Grounding of Electrical Installations on Customer's Premises; *A. H. Schirmer (Bell Telephone Laboratories, Inc., New York, N. Y.).*

In the early days, when electricity was used primarily for lighting and convenience outlets and appliances were practically unknown, the main reason for grounding secondary circuits was to reduce the hazard resulting from primary voltages. Today, with better transformers and transformer protection, as well as improved pole line construction, faults involving primary circuits are relatively rare. On the other hand, more and more appliances are being used in the home and factory so that protection from low-voltage faults has become the more important consideration. It seems wise, therefore, to discuss low-voltage protection in detail, particularly since the grounding and bonding required for adequate low-voltage protection is in general adequate for primary voltage and lightning protection.

The code requires secondary circuits to be grounded if they can be so grounded that the maximum voltage to ground does not exceed 150 volts. Except in public water pipe areas, it is in general not practicable to secure a grounding electrode which has a resistance of less than ten ohms. In view of this, satisfactory low-voltage protection cannot be obtained ordinarily where separate grounding electrodes are used for circuits and equipment. For adequate protection it is necessary to have a common grounding electrode for circuits and equipment at each building served.

The use of a public water system as a grounding electrode is well established. It is also important to use so-called private water systems, that is, systems supplied from local wells. It is recognized that, in general, the resistance to ground of such systems will be materially larger than for public systems. It is nevertheless important to use such a system as the grounding electrode or to bond it to any other electrode which may be used. The use of such private water systems as a grounding electrode reduces the likelihood of differences of potential within a building. It also reduces the likelihood of failure in electric hot water heaters and motors on water pumps where the enclosures are in contact with the water pipes.

The present extensive practice of interconnecting primary and secondary neutrals improves the effectiveness of grounding, particularly in rural areas. It also has definite advantages from both the standpoint of lightning and faults involving primary distribution circuits.

Tests on Power Cables at Carrier Current Frequencies; *C. S. Murray (Consolidated Edison Company of N. Y., Inc., New York, N. Y.).*

The application of carrier-controlled relaying to the interconnections of an underground transmission system often has been considered in the past. However, from the small amount of available information dealing with the high-frequency losses of power cable, it was concluded that the losses of the cable were too high to permit use of the cable itself for transmission of the carrier signal. This would necessitate using coaxial cable but this was considered to be impracticable in most cases in view of the cost.

During 1942 a number of high-frequency measurements were made on a 3-mile length of oil-filled cable. Because of the cross-bonding of the cable, the losses were fairly high, being in the order of five to six decibels per mile. Further measurements, made with the cross-bonding eliminated, showed that the losses would be in the order of one to three decibels per mile. It was believed that in future installations where cross-bonding did not exist, the problem of transmitting the carrier signal over the power cable should be given further consideration.

Soon after the war, the Consolidated Edison Company began an expansion program and the latest types of power cable were considered for the interconnections of its 138-kv transmission system. Oil-pressure-pipe-type cables were selected.

An inspection of the oil-pressure-pipe-type cables showed that this type might possess inherent characteristics which were satisfactory for the transmission of the carrier

frequency signals. Since it was desirable to apply carrier-controlled relaying on some of the interconnections, a program was set up to obtain carrier frequency characteristics of the cable soon after the completion of each interconnection. To date, measurements have been completed on two sizes of cable of different manufacture.

Based on the test results obtained to date, it appears that, for cables of the type tested, more sensitive relaying receivers may be necessary than those usually employed on overhead lines. The losses in the coupling circuit, when connected to the cable, become an appreciable amount of the total losses to be considered. This fact had been known for some time but no data were available which would show the actual magnitude of these losses, and opinions varied over a considerable range of values. Actual measurements made on one coupling circuit connected to an oil-pressure-pipe-type cable of 23-ohm surge impedance showed that this loss may amount to as much as six decibels per terminal at 60 kc. The total losses, cable plus coupling, for a 10-mile underground feeder consisting of 1,500,000-circular-mil oil-pressure-pipe-type cable and with line-to-ground coupling, may amount to the order of 42 decibels at a carrier frequency of 60 kc.

The Characteristic Impedance of Power Cables at Carrier Current Frequencies; *A. A. Sackler* (*Ebasco Services Inc., New York, N. Y.*).

The increasing use of high-voltage cables for the transmission of electric power has made it necessary to determine the characteristic impedance of these cables at carrier current frequencies in order to apply carrier current channels to such lines.

Tests were made on 8.1 miles of 138-kv 350,000-circular-mil oil pressure pipe cable to determine its characteristic impedance. The line was long enough so that changing the termination at the receiving end did not affect the input current and voltage. Therefore, characteristic impedance was taken as E/I. Tests also were made using a radio-frequency bridge to determine the characteristic impedance. The results obtained by the radio-frequency bridge did not agree over the entire frequency range with the results obtained by the first method.

The phase-to-ground characteristic impedance as found by the E/I method, varied from approximately 78 ohms at 30 kc to a low of 50 ohms at 85 kc and then back up to 68 ohms at 150 kc. With the radio-frequency bridge, the impedance was measured at 38 ohms at 30 kc, 47½ ohms at 85 kc, and a high of 57 ohms at 150 kc. This latter result agrees fairly closely with the calculated characteristic impedance of 43 ohms.

In a phase-to-phase test, the E/I method showed the cable to have a characteristic impedance of 138 ohms at 30 kc, 82 ohms at 100 kc, and 100 ohms at 150 kc. With the bridge, the impedance was found to be 75 ohms at 30 kc, 82 ohms at 100 kc, and 102 ohms at 150 kc. From 80 kc to 150 kc, the results obtained by the two methods agree within a few per cent. The calculated phase-to-phase impedance is 83 ohms.

It was found also that the two impedance curves obtained with the radio-frequency bridge have similar shapes, the only difference being that the phase-to-phase curve was approximately twice the amplitude of the phase-to-ground curve, which is to be expected.

The necessary communication needed for making the tests was obtained by connecting sound power telephones from one phase of the cable to ground. It was found that sufficient cross-talk existed between phases to allow satisfactory communication to take place with the telephones connected to different phases at each end of the cable. This indicates that an appreciable amount of common impedance exists between the phase conductors.

We also have studied characteristic impedance tests which were made on approximately 25,000 feet of 69-kv oil compression pipe cable by still another method. This cable was short enough so that changes in the cable termination could be detected at the input end. The voltage and current at the input end of the cable were measured with the cable open-circuited and short-circuited at the far end. The open-circuit and short-circuit impedances are equal to input E/I. The characteristic impedance was calculated from the equation: $Z_o = \sqrt{Z_{s\cdot c} \times Z_{o\cdot c}}$, where Z_o is the characteristic impedance and $Z_{s\cdot c}$ and $Z_{o\cdot c}$ are the short-circuit and open-circuit impedance.

The phase-to-ground characteristic impedance as determined by this method was found to be 28 ohms at 50 kc, 30 ohms at 100 kc, and 32 ohms at 150 kc. The phase-to-phase characteristic impedance was found to be 58 ohms at 50 kc, 52 ohms at 100 kc, and 54 ohms at 150 kc.

On this cable telephone communication was established also from one phase to ground but no cross-talk was evident.

The relatively erratic changes of characteristic impedance with changes in frequency would seem to indicate that the measurements taken by all three methods are affected by phenomena requiring further study.

Bridge for Direct Measurement of Resistance at Carrier Frequency; *A. H. Burkhalter* (*Ebasco Services Inc., New York, N. Y.*).

The art of applying power line carrier has progressed to such a stage that the difficulty of direct measurement of electrical quantities at carrier frequency is a handicap.

The thermal galvanometer provides a convenient means for measuring current at carrier frequency. The vacuum tube voltmeter provides a fairly convenient means for measuring voltage but requires an instrument of laboratory quality. No instrument is readily available for direct measurement of carrier-frequency resistance.

It is possible to build a simple resistance bridge out of readily available parts, which is quite accurate at carrier frequency.

The material required for such a bridge can be purchased for about $15. The material consists of a small metal cabinet, a 0–150 microampere meter, three precision resistors, a 3-position selector switch, two wire-wound potentiometers, one *1N34* rectifier, one by-pass capacitor, and miscellaneous binding posts and hardware.

The bridge can be used as a resonance indicator in the carrier coupling capacitor resonating circuit since it reads unbalance for anything other than resistive load. It can be used also to read the ohmic value of the output load resistance represented by a resonating network plus a power line on which carrier signal is being applied. It can be used to measure primary impedance of a matching transformer to aid in selecting proper impedance ratio to match known characteristic impedance of coaxial cable. It is also possible to calibrate the indicating meter on the bridge in mismatch ratio for a resistance setting equal to characteristic impedance of coaxial cable. Since this mismatch ratio is numerically equal to standing wave ratio cable, it is thus possible to take standing wave ratio readings of a coaxial cable used to transmit carrier signal.

This bridge was used recently to measure characteristic resistance of a 138-kv power cable. The readings taken by the bridge were found to closely approximate over a certain frequency range the value found by E/I measurements. Over the frequency range where the results differ, it has not been determined which value is the more accurate.

Loss Measurements Made on Underground-Cable Overhead-Conductor 132-Kv Transmission Line at Carrier Frequencies; *H. A. Cornelius* (*Public Service Company of Northern Illinois, Chicago, Ill.*), *B. Wade Storer* (*Commonwealth Edison Company, Chicago, Ill.*).

The major problem is how to secure more carrier power over a 37-mile-long line which includes 5.8 miles of underground lead-covered cable which has the sheath insulated at intervals but connected through sheath bonding transformers. Other complications are

1. A large impedance mismatch at the junction of the underground cable and overhead conductors.
2. A tap to the overhead section.
3. Two other 132-kv lines on the same right of way.
4. The presence of an electric railway on the right of way which increases the noise level.

The procedure followed was to determine the loss in each part or component of the circuit by utilizing transmitters now in service and such additional equipment as was needed for the tests.

The results obtained for the various pieces of equipment at the Northwest terminal are as follows:

Wave traps—3,700 ohms at 75 kc
Coupling capacitor with drain coil:

Frequency (kc)	50	75	100	150
Resistance in ohms	36	30	26.5	22.5
Loss in decibels	3	2.8	3.0	3.2

50-foot lead in wire supported on insulators:

Frequency	50	75	100	150
Loss in decibels	2.8	2.8	2.6	2.7

Line tuning coil:

Frequency	50	75		150
Resistance in ohms	21	24.4		60

The results obtained at the Waukegan terminal are as follows:

Wave traps—3,600 ohms at 75 kc
For complete terminal:

Frequency	50	75	100	150
Loss in decibels	3	3	2	2

The characteristic impedance of the underground cable was found to be as follows:

Frequency (kc)	50	75	100	150
Characteristic impedance	42.5	38.2	28.5	31.0

The input resistance, input impedance,

and the attenuation of the underground cable varied with frequency as follows:

Frequency Kc	Input Resistance Ohms	Input Impedance, Ohms	Attenuation, Decibels
50	35.0	42.5	25
75	33.2	38.2	29
100	27.0	28.5	36
150	20.5	31.0	53

The overhead conductor attenuation losses were as follows:

Frequency (kc)	50	75	100	150
Loss in decibels	4	5	6	9

The total attenuation loss for the entire line or circuit was 52.3 decibels at 75 kc.

Looking from the 33-ohm cable section into the 435-ohm overhead conductor section the mismatch loss at 75 kc was found to be 5.8 decibels.

Signal and noise strength measurements were made also.

On a clear, dry day the following signal-to-noise ratios, at 75 kc, were found:

Location	Northwest	Skokie	Waukegan
S/N ratio	314:1	105:1	74:1
Noise, microwatts			0.15

Since more measurements are planned, no conclusions have been made to date.

Steam and Electrical Balance in Chemical Plants; *L. W. Roush (Carbide and Carbon Chemicals Corporation, South Charleston, W. Va.).*

Most chemical plants require large quantities of low-pressure steam for heating and processing.

If the steam is generated at higher pressures and temperatures than required in the plant operations, the excess energy may be used to generate electric power by passing the steam through turbogenerators.

As the electric power thus generated is a by-product of the required plant steam generation, the cost of electric power generation being only the excess cost over that of generating the steam, is exceptionally low.

The problem of making the steam do double duty by generating by-product power and then providing the plant with heat and process steam seems simple but actually is a very complicated design problem.

Most plants require steam at three different pressures and temperatures and some have several more. The quantity of steam at any one pressure is varying continually. Also the ratio of total steam consumption to the electric load varies continuously.

A fairly simple installation might require steam at 180, 50, and 10 pounds pressure. The boiler installation would have sufficient capacity to supply the maximum steam requirements for plant consumption and generation of electric power. The steam generation might be at 600 pounds and 700 degrees Fahrenheit temperature. The back pressure turbines would exhaust at 200 pounds.

The designer has a number of methods for securing a steam balance and a balance between the steam and electric loads.

The lower pressures and temperatures may be secured with expansion valves and desuper-heaters. Turbines and steam pumps of various capacities may utilize steam at various pressures and exhaust at various pressures or to condensers. Internal steam balance may require various combinations of blowdown flash tanks, heat exchangers condensate flash tanks, feed water heaters and drives for boiler feed pumps, induced and exhaust fans, ash removal, and so forth.

If the electric load becomes excessive it may be necessary to vent some steam.

The steam and electric balances are designed to operate automatically. However, the plant and power plant operators can assist in securing maximum economy by using arrangements to minimize wastes.

In most plants the electric load is, or could be, much in excess of the possible generation as by-product power.

In such plants if a connection with a public utility is available the balance problem between the steam and electric loads is solved automatically. Both the steam and electric applications can be developed for the best advantage of each.

There are some disadvantages with a utility connection.

Continuity of electrical service is very essential in chemical plants. In some processes the loss of power may be critical and dangerous. For some operations even a momentary loss of power will cause process shutdowns of long duration. The loss of production and the expense of getting into production again is costly.

Utility connections cause outages due to faults on the exposed transmission systems. Surges originating on their lines are carried into the plant often causing outages. Synchronous motors are especially sensitive to voltage surges. The short-circuit capacity of the plant electric system must be increased. The cost of electric power and the electrical installation is increased.

As the plant grows, various expedients are used to help the balance. Extraction or bleeder turbines may be used to advantage by supplying steam at several pressures and temperatures. Small steam turbine drives replace electric motor drives. Steam pumps replace electric. Various types of heating replace electric heating which has such excellent control features. The sum of such installations adds to the operating difficulties and over-all production costs.

For some plants a very satisfactory solution for the steam electric balance problem is to generate all electric power requirements in excess of by-product output with condensing turbines. Both the steam and electric installations have no restriction in their development for the most economical plant operation. The result will be that more equipment will be operated electrically. The disadvantages of utility line connections will be eliminated. The increase in the total electric power cost will be moderate.

The primary steam pressure of a by-product plant is dependent on the economics of the chemical treatment of the feed water and the amount of makeup. The relative amount of makeup will be large as a small proportion of the steam used in chemical plants is returned as condensate. Some of the steam is used in processing, some is loss to atmosphere through venting and leaks and some is so contaminated that it cannot be redeemed economically. As high steam pressures and temperatures require costly feed water treatment, there is an economical limit to these values for the conditions obtained in any given plant.

In general, a steam pressure of 400 pounds is the lowest economical limit for a by-product plant. A steam pressure of 600 pounds with a temperature of about 700 degrees Fahrenheit has been used satisfactorily for many years but now is considered as rather conservative. Improvements in feed-water treatment permit the use of 900 pounds steam pressure with 750 degrees Fahrenheit temperature for most locations. For the design of a new plant a steam pressure of about 900 pounds and a temperature of about 800 degrees Fahrenheit probably would be selected for most locations. The selection of condensing, extraction, and back pressure turbines would depend upon the plant steam and electric requirements.

Rectifier Transformer Characteristics; *Rectifier Transformer Subcommittee of AIEE Electronic Power Converter Committee.*

Rectifier circuits are classified as single-way or double-way, depending upon the polarity of the current pulses which flow in the d-c windings of the rectifier transformer. Single-way circuits are most common in power rectifiers, and require a transformer with an even number of d-c windings per a-c winding. These windings must be interlaced carefully, and symmetrically disposed with respect to the a-c windings, if satisfactory operation is to be obtained.

Structurally, rectifier transformers are similar to power transformers, but with such modifications as required by the arrangement of windings. Further modifications are required successfully to withstand the mechanical forces attending fault currents much higher than the limiting value for power transformers.

The voltage of the d-c windings, the reactance, and the resistance of the transformer largely determine the electrical performance characteristics of the rectifier. Transformer nameplate data are sufficient approximately to determine the performance of a given circuit, while more accurate performance characteristics are calculated readily when the needed factors are known.

Fault current magnitude is determined largely by the voltage and reactance of the transformer together with the arc drop of the rectifier elements. Good regulation of the rectifier direct voltage and low fault current are mutually incompatible, so a compromise must be achieved. The crest value of fault current, in the d-c winding of the transformer during arc-back, for a 600-volt rectifier of normal regulation, will be of the order of 50 times the normal rms current for the winding.

The mechanical forces between leads, windings, and portions of windings, as well as the forces on core clamps and other structural parts, resulting from fault currents of this magnitude are very high. To withstand these forces, the mechanical design of transformer, as well as the materials used, must be of the highest order.

Current Practice in Rectifier Switchgear; *M. E. Reagan (Westinghouse Electric Corporation, East Pittsburgh, Pa.).*

The protection of early rectifier installa-

tions closely followed the protective pattern adopted for rotating equipment of that day. The progressive increase in unit ratings, with attendant increase in severity of arc-backs, prompted gradual improvements in relay and circuit breaker speeds, arc suppression schemes, and high-speed anode circuit breakers. The principal differences between protective systems as applied today are mainly due to the differences in ratings and the number of units. Since rectifiers provide very close coupling between the a-c and d-c systems, protection must be planned carefully to prevent disturbances in both systems in case of arc-back.

The protective system of a rectifier includes the a-c circuit breaker, transformer impedance, anode circuit breaker, the rectifier itself if arc suppression is used, the cathode circuit breaker, d-c reactor, and feeder circuit breakers. These elements are used in various combinations to effect the desired results. While an anode circuit breaker may provide all the protection necessary for the rectifier, other means must be included to protect the transformer and auxiliaries and to facilitate switching and control.

Protective systems must be highly selective to insure maximum continuity of service without sacrificing protection. In multiple-unit installations, selectivity between units is of great importance. The high-speed anode circuit breaker with reverse current trip per pole, in combination with inverse time relays for the a-c circuit breaker and time overcurrent trip on the cathode circuit breaker, provides a high degree of selectivity. If there are d-c feeder circuit breakers, selectivity between the a-c circuit breakers, cathode circuit breaker, and feeder circuit breakers is obtained by time overcurrent relays for the a-c circuit breaker, time overcurrent trip for the cathode circuit breaker, and instantaneous overcurrent trip for the feeder circuit breakers.

In the absence of the anode circuit breaker, instantaneous reverse current tripping of the cathode circuit breaker usually will provide the required selectivity if the overcurrent trip on the d-c circuit breaker either is made time daily or omitted entirely.

Rectifiers supplying essential lighting and power loads in public buildings must possess a high degree of selectivity, because continuity of service is of the utmost importance. Arc-back interruption must be extremely fast to minimize objectionable flicker of the lights. These requirements are met by high-speed cathode circuit breakers with reverse current trip and low-voltage a-c circuit breakers with short-time overcurrent trip.

Since arc-backs do not seriously damage a rectifier unless sustained or repeated frequently in rapid succession, automatic reclosers for the circuit breakers frequently are included.

Protection is provided for the transformer, rectifier, and auxiliaries against all abnormal operating conditions in accordance with American Standards Association Standards.

Rectifiers lend themselves readily to completely automatic control, the starting and stopping sequences being relatively simple. Load responsive control frequently is included to start and stop the units in accordance with load demand, and supervisory control is used to control the rectifier units from a central point, either independently or in combination with load responsive control. Telemeters are used as a means of observing the station loads at the central control point.

Synthetic Load for Testing Rectifiers; *C. L. Tetherow (Underwriters' Laboratories, Inc., Chicago, Ill.).*

Metallic rectifiers designed specificially for charging electric storage batteries present unusual problems in the selection of satisfactory test loads. Conventional resistance loads are unsatisfactory since the operating characteristics obtained from storage battery loads are considerably different from those obtained by resistance loads.

In attempting to obtain comparison between different designs of rectifiers, storage battery loads are not recommended for testing purposes. No two batteries will exhibit identical charging characteristics and it is extremely difficult and certainly impractical to obtain similar charging characteristics from any specific battery for a number of charging cycles. The following variable conditions have a distinct bearing on the charging characteristics of a given battery:

(*a*). Age of the battery.

(*b*). Number of times cycled.

(*c*). Rate of discharge.

(*d*). Amount of total discharge.

(*e*). Length of time allowed to stand idle between charges.

(*f*). Degree of sulphation of plates.

(*g*). Condition of the battery solution.

In order to obtain reliable comparisons between input, output, and temperature characteristics of various metallic rectifier designs, it is obvious that a standard test load simulating battery characteristics is extremely desirable. An analysis of the output voltage and current wave forms obtained from a metallic rectifier when charging a storage battery indicates that a pronounced flat portion on the voltage wave causes the current wave to deviate considerably from a simulated full rectified sine wave shape. The use of capacitance in parallel with a variable resistance on a synthetic load prevents the voltage from dropping to zero value between rectified current pulses. Although the output voltage waves are not identical, the effect on the output current wave of the synthetic load is remarkably similar to that obtained from a storage battery load. Although the amount of capacitance used is not too critical, a value of 100,000 microfarads is recommended as a substitution for a single 6-volt storage battery.

A synthetic load consisting of the proper amount of capacitance in parallel with a variable resistance appears to provide an effective method for establishing a uniform test procedure for metallic rectifiers intended for charging storage batteries. It provides distinct advantages over a resistance load inasmuch as the operating characteristics of the rectifier are nearly identical to those obtained when a storage battery test load is used. It provides a simple positive means of controlling the load which is impractical to obtain by using storage batteries. In addition to eliminating the problem and inconvenience of maintaining a large number of various size storage batteries, it is also more economical. The use of the synthetic (capacitance-resistance) load has gone far towards solving the problem of a standard test load for metallic rectifiers intended for charging storage batteries.

Elliott Gas Turbine Developments Applicable to Power Generation; *Edward S. Dehnison (Elliott Company, Jeannette, Pa.).*

Starting in the year 1942, Elliott Company designed and built a 2,500-horsepower marine gas turbine. The project was sponsored by the United States Navy Department, and proceeded to completion in December 1944. At that time acceptance trials were passed successfully, the plant showing 29.2 per cent thermal efficiency at an output of 2,379 horsepower. Three additional similar plants were ordered and these now are nearing completion. Designed output is increased to 3,000 horsepower, with provision for overload, and turbine inlet temperature is increased from 1,200 degrees Fahrenheit to 1,400 degrees Fahrenheit per cent thermal efficiency. The marine plants are characterized by a compound cycle, with two rotating assemblies, and efficient performance extends down to a rating of about 30 per cent output.

In addition, two simple-cycle locomotive turbines of 3,750-horsepower rating are being built. Rated load efficiency is designed to be 24.9 per cent, but at part load efficiency drops rapidly because of the simplified arrangement and the absence of compressor intercooling.

Both plants were designed as propulsion units, but both exhibit valuable characteristics as constant-speed tower plants. The compound-cycle plant is characterized by high thermal efficiency extending over a wide range of load.

The simple and compound plants are regarded as typical of two divergent lines of development open to the gas turbine. A simple plant has the advantages of easy installation and of freedom from cooling requirements. The compound type is more costly, and requires some cooling water, but is competitive thermally with a good condensing steam plant. Both types appear to have a wide field of usefulness open to them within the near future.

The marine gas turbines employ the Lysholm positive displacement compressor. This type offers satisfactory performance and has the advantage of being free from instability. However, its operating speed and some other characteristics do not lend themselves to the requirements of the gas turbine, and an aerodynamic type of compressor is more attractive. The centrifugal compressor is of rugged design and relatively inexpensive. Its inherent efficiency is not equal to that of the axial type, but it is better adapted to several steps of intercooling. It is regarded as a very satisfactory component of power-generation gas turbines.

Reduction of cost of the gas turbine component proper is a necessity. Progress in this direction can be made by employing a minimum number of turbine stages, and by holding metal temperatures to such a level that inexpensive alloys can be used.

Plant economy is improved materially by the addition of a regenerator. Direct savings in a simple-cycle machine are so great that the regenerator will pay for itself in about one year's operation. Tubular regenerators offer no particular design or

manufacturing difficulty. Extended surface types are promising as a forthcoming development, but are not on a commercial basis today.

Gas turbines are capable of burning low-grade heavy fuels, and may use natural gas in regions where that fuel is readily available. Transition to coal fuel is an important objective. Excellent work is being done toward internal combustion of pulverized coal. External combustion, with a "dry boiler," is a second possibility which also deserves consideration.

A Design of Gas Turbine Suitable for Peak-Load and End-of-Transmission-Line Operation; *W. B. Tucker* (*Allis-Chalmers Manufacturing Company, Milwaukee, Wis.*).

Load conditions exist on some power systems where the utility of the gas turbine will meet the requirements better than any other type of power generating equipment. A gas turbine to be described is believed to be generally most suitable for two types of power system requirements; namely, peak load, and end-of-transmission-line operation.

The general requirements for such systems are

(*a*). High order of reliability.

(*b*). An acceptable first cost of complete installation economically to justify the necessary expenditure.

(*c*). Minimum facility requirements; such as water, buildings, foundations, auxiliaries, and the like.

(*d*). Quick starting.

(*e*). Minimum of attention by operators when starting, operating, stopping, and during shutdown periods.

(*f*). Efficiency that is high enough economically to permit desired duration of operation under each particular condition of fuel cost.

The gas turbine in question is a 7,500-kw 3,600-rpm single-shaft simple-cycle turbine with regenerator unit direct-connected to a generator of like speed, operating at 1,300 degrees Fahrenheit and pressure corresponding to 1,000 foot altitude when delivering 7,500 kw to the generator terminals.

The approximate fuel-to-bus efficiencies with 50 per cent effective regenerator will be 22.2 per cent for oil, using the lower heat value.

The prime mover element is a 6-stage reaction turbine designed to deliver 32,000 horsepower to the compressor coupling.

The turbine spindle body is a fabricated construction consisting of six equal diameter disk forgings which are machined and welded together to form the blade-carrying portion of the spindle. Stub ends are welded to each of the end disks to form the bearing and coupling ends of the spindle. This type of spindle has been used successfully in a number of gas and steam turbines.

The first rows of blading may be precision cast while the last rows will be forged to shape. All blades will be of the *S-590* material. The roots of the cylinder blades are machined to fit in circumferential grooves in the cylinder rings. The spindle blades will have axially serrated roots to fit the spindle grooves.

The compressor is of the axial flow type and is placed between the turbine and generator. This arrangement allows sufficient space for a regenerator to be placed in the cycle in a position above the turbine and compressor.

The compressor rotor body with an integral stub end at the low pressure end is made from a single forging. The stub end at the high-pressure end also is made from a forging and is bolted to the high-pressure end of the rotor body and located with a forced centering fit.

The upper and lower halves of the compressor casing are fabricated from shaped steel plates or made from a casting and circumferentially grooved to receive the stationary compressor blading.

All compressor blades have integral spacers and may be precision cast with accurately machined roots for fitting in the rotor and casing grooves.

The fly-ball-type speed control governor is driven from the turbine shaft. This governor operates to maintain the desired speed by controlling the rate of fuel flow to the combustor.

In order for the gas turbine to be available for quick starting after shutdown, a turning gear, located in the bearing housing between the compressor and generator will maintain proper thermal equilibrium by turning the rotating elements.

The size of the regenerator is based upon economic considerations and space available.

An Operating View of the Problem of Fluctuating Loads on Steam Plants; *G. H. McDaniel* (*American Gas and Electric Service Corporation, New York, N. Y.*).

In the last 20 years, the continued expansion of interconnections has necessitated the use of automatic control to regulate frequency and tie lines. The inherent power swings on tie lines and internal load fluctuations from minute to minute on the systems are being regulated automatically on steam plant equipment within the ability of the units and boilers to respond to such control. As new high-pressure high-temperature boiler and turbine equipment is placed in service on interconnected companies, it becomes necessary to review the load changing flexibility of such equipment.

The writer is suggesting that governors be maintained on existing units in a high state of maintenance to obtain positive action under automatic control, and that the design of governors on new units be such as to attempt to attain straight-line response on the generator output at the time the synchronizing motor or hydraulic valve is actuated. The writer is suggesting also that future boiler design be of such quality as to permit such flexibility of automatic load control as is needed to control system load without duress occurring in the boiler equipment. The writer is suggesting further that in the future the barrier existing between the turbine room and the boiler room be broken down and that automatic control be extended from the turbine to the boiler combustion control, in order to permit over- or underfiring for load regulation purposes to occur, rather than wait for a response in pressure variations.

In summarizing, the writer suggests the maintenance of governor systems, the design of turbine control valves, boiler equipment, and the system tying together of automatic frequency and tie line control from the turbine to the boiler should result in an adequate and reliable control of load distribution in order to wipe out load fluctuations occurring within an area without placing an undue burden on interconnecting tie lines.

Kenotron Tubes for Industrial Precipitation Applications; *D. W. Hawkins* (*General Electric Company, Schenectady, N. Y.*).

High vacuum electronic rectifier tubes have been used to supply d-c power for precipitators for many years. In the higher voltage applications where mechanical rectifiers have been commonly used, the electronic rectifier is gaining popularity. Beside the advantage of space saving and elimination of ozone and nitrous oxide, the electronic rectifier is very dependable and requires infrequent attention when properly installed and operated. An average tube life of 20,000 to 30,000 hours has been obtained in conservatively operated rectifiers using *KC-4* Kenotron tubes.

Early prejudice against the electronic rectifier generally resulted from short tube life caused by inadequate tubes and power supply equipment and lack of understanding of proper tube operation. The high-voltage rectifier tube which has a pure tungsten filament, must be properly protected from overload and under filament voltage to prevent excessive tube plate dissipation and consequent tube destruction. For long tube life, the filament voltage must be kept as low as possible consistent with proper operation for a given load. Filament evaporation (life) doubles with a five per cent decrease in filament voltage and halves with a six per cent increase. The filament voltage required is determined by the peak value of plate current taken from the tube. Consequently, low peak to average plate currents in a power supply allow lower filament voltages and give longer tube life as a result.

The pure tungsten filament rectifier tube, such as the *KC-4*, is not subject to steady deterioration if not used, as frequently is believed.

In lower voltage applications, 15,000 volts or less, small thoriated tungsten rectifier tubes generally are used. The *GL-8020* is such a tube. These tubes are relatively inexpensive and very reliable. Filament voltage regulation is not so critical in this type of tube as in the larger pure tungsten filament type.

Practice and Extent of Backup Protection; *W. L. Ridenhour* (*Pennsylvania Water and Power Company, Lancaster, Pa.*).

The material contained in this paper is the result of work by the Pennsylvania Electric Association relay subcommittee. The study of the problem of protecting electric equipment and electric systems from damage caused by sustained faults was divided into two parts, the first being to determine the actual practices of the member companies, and the second to determine what philosophy should be used as a guide when determining what backup or second-line protection is necessary in a specific case. Backup protection is defined as any relay or protective system which will operate to clear a faulted equipment in the event that the devices which normally would clear the fault fail to operate. Equipment having no primary protection still may be cleared by "backup" relays designed to protect other equipment.

With regard to the first objective of the study, it was found that in the majority of cases relay systems of the type which provide no inherent backup, such as carrier, pilot wire, differential, current balance, usually

are provided with backup relays. Frequently this backup is installed more for the purpose of providing protection when the primary relays are out of service and for protection of adjacent line sections than as insurance against failure of the primary relays to operate. Overcurrent and distance relays usually provide some measure of protection for adjacent equipment and consequently are not "backed up" in many cases.

Power transformer differential relays are backed up in about 50 per cent of the cases reported. Generator differential protection usually is considered to be sufficient.

When backup relays are installed as such, it was found that in about 50 per cent of the cases reported only the primary relays themselves were protected against failure, while in about 30 per cent of the cases, relays, instrument transformers, and trip circuits were provided with backup protection.

The opinions expressed as to a workable philosophy for determination of backup requirements were naturally somewhat variable because different emphasis is placed on continuity of service, protection of equipment, economy, and so on, by the different members. It was believed that backup protection could be likened to insurance, that the amount of secondary protection could be determined somewhat on the record of failures, and that backup requirements could be minimized by adequate maintenance.

A set of criteria is suggested which may be useful as a guide when faced with a decision as to the amount of backup protection which can be justified. These include the following:

1. Can a failure to clear faults cause a severe system disturbance?
2. What is the probability of relay failure?
3. What is the expected frequency of faults?
4. To what degree is backup protection inherent in other relaying?

It is concluded that it may be possible to establish general rules for an analysis of the problem, but that general approval of a particular scheme for providing backup protection cannot be given for the reason that each application is different and must be engineered in the light of its own requirements.

Backup Protection Studies; *L. W. Marts (Public Service Electric and Gas Company, Newark, N. J.).*

To meet the challenge of increasing load, the development of primary relaying has been rapid and continuous. Progress in backup protection, however, has lagged far behind or been at a complete standstill. If any link in the primary protection fails—from battery to relay to circuit breaker—high-speed clearing of the fault is impossible and the consequences are those which justified the high-speed primary protection.

A review of present-day backup relays and techniques reveals that:

1. Cascaded time settings generally are required for distance relay backup protection because of variations in reach with switching and generation changes. Such time settings are usually outside stability limits.
2. Automatic segregation of a system into areas of balanced load and generation in the event of sustained trouble in some cases can be effected nonselectively to diversify the risk and thereby avoid a complete system interruption.
3. The most economic solution for an inoperative circuit breaker is to install a timer actuated by the primary relays which will trip the associated bus section if the normal circuit breaker fails to open.
4. Backup protection in general is limited severely by transmission layout and station bus design. The backup relay problem should be considered carefully in proposals for system expansion.

In principle, the performance of backup protection should equal that of the primary equipment. The attainment of this objective with simplicity and economy is not in the foreseeable future, but the current interest in backup relaying is a hopeful sign.

Radioactive Tracers in the Study of Friction; *John T. Burwell, Jr. (Massachusetts Institute of Technology, Cambridge, Mass.).*

Modern theories of the mechanism of the dry friction between averagely smooth metal surfaces attributes most of the friction force to the shearing of many very minute welds. These welds are formed over the isolated minute true contact areas that collectively support the load holding the two surfaces together. The sum of all these true contact areas amount to only one thousandth or less of the total surface area which is nominally in contact. In many cases, especially if the metals in question tend to work-harden, one would not expect the welds to shear exactly along the original surface of contact but rather to shear slightly to one side or the other, thus leaving a minute blob of one metal adhering to the other surface. Confirmation of the foregoing hypothesis by direct detection of this transferred material has been difficult, not only because of the very small amounts involved, but also because of the uncertainty as to its exact location on the nominal surface of contact. However, technique employing radioactive tracers has been found to be directly applicable to this problem. Essentially, it consists of making one of the two rubbing surfaces radioactive, carrying out controlled friction experiments, and then examining the second surface for evidence of radioactivty. It can be shown that mere proximity will not induce any activity in the second surface; actual material from the active surface must be transferred. Using this technique, evidence of material transfer upon rubbing has been found between a variety of metals, both dry and lubricated. The amount transferred can be determined quantitatively by means of a Geiger counter and its distribution over the surface by means of a photographic film.

The amount of transferred material was found to be greatly reduced by the presence of a lubricant. It was found to vary systematically with the hardness of the surfaces so long as the composition of the surfaces remained the same. Differences in composition have a marked effect on the transfer, as have various surface treatments. Since this friction phenomenon is essentially a "microgalling" it is of interest to mechanical engineers in serving as an indicator as to how easily certain rubbing materials may be expected to fail by scuffing or galling upon breakdown of lubrication. Moreover the observations are essentially nondestructive of the test specimens. This phenomenon may be of interest also to electrical engineers as a similar type of friction is encountered in sliding electric contacts, brushes, commutators, and so forth. Furthermore, the radioactive tracer technique may be of interest in studying the transfer of metal between current-carrying contacts of switches and circuit-breakers. This work has been supported in great part by the Chrysler Corporation and in part by the National Advisory Committee for Aeronautics.

Quantitative Radiation Dosage Measurements by Autoradiographic Techniques; *R. A. Dudley (Massachusetts Institute of Technology, Cambridge, Mass.).*

The purpose of this paper is to describe methods of determining the magnitude of local radiation dosages from radioactive isotopes nonuniformly distributed throughout an inert material. The techniques have been applied to biological problems but can be readily extended to other types.

Of all the instruments for the detection of atomic radiations, photographic film is the only one suitable for this purpose. Whereas other instruments can measure only average source activity over a fairly large area, film is capable of measuring activity over source areas as small as 0.01 square millimeter.

The procedure is to expose a flattened surface of the material containing the radioactive isotope (for example, bone containing radium) to an appropriate emulsion, maintaining good contact. The radiations produce an "image" on the film which is called an autoradiograph. The quantitative determination of the local exposures may be made in one of two ways. For all types of radiation, provided the intensity is high enough, the degree of local blackening may be measured by means of a microphotometer. Absolute calibration, relating exposure to blackening, is obtained by producing on the same film a set of control exposures from sources of known activity. This method has been used by the author in determining the radiation dosage rate from Ca^{45} in bones. Dosage rates equivalent to a source activity of 0.05 microcurie* per gram bone over a surface area of about 0.05 square millimeter have been detected with an accuracy of about 20 per cent.

A second method of quantitation is useful for analyzing low activity sources containing alpha emitting elements. In this case one uses a "nuclear track emulsion," an emulsion in which the individual particles leave detectable tracks. The exposure is measured by counting, with the aid of a microscope, the number of alpha tracks per unit area. Some tracks will be too short to be detected, and therefore, a calibration source of known activity is used. The observed number of tracks from the calibration source is compared with the theoretical number of tracks, and the minimum detectable track length is thereby computed. Using this figure, the fraction of undetectable tracks in the autoradiograph can be calculated and corrected for. By this method the author has measured quantitatively, with an accuracy of about 15 per cent, radium concentrations in bone of a few millimicrograms radium per gram bone over an area on the bone surface of 0.01 square millimeter. Further improvements by the photographic manufacturers in the sensitivity of these particle emulsions may permit the same type of detection of beta rays. This is a step which greatly would extend one's ability to analyze low activity beta sources.

*1 microcurie = 3.7×10^4 disintegrations per second.

A Servomechanism Analysis of a Photoelectric Loop Control; *L. U. C. Kelling* (*General Electric Company, Schenectady, N. Y.*).

This servomechanism analysis is made of the photoelectric loop control system which regulates the position of a loop of a strip material being fed from a coil to a continuous steel strip processing line. The equipment has been working successfully for several years. This analysis is made to compare actual physical performance with that which would be arrived at by purely theoretical considerations.

This paper presents a solution to a control system problem in which conditions change over wide ranges. For a given material strip speed the total connected inertia of the motor changes over a range of 15 to 1 and the speed changes over a range of over 3 to 1. The analysis of the control system is made for several sets of conditions which cover the range of variations. Detailed solution is made of the various factors which change over the range of conditions. The servomechanism analysis is made by means of the H. W. Bode gain and phase margin curves with performance check by *M* curves plotted from N. B. Nichol's chart.

The basic calculations are made on the basis of design data on the motor rather than actual tests. The theoretical analysis shows less stability than achieved in actual installation of the control.

Improvements in the Characteristics of A-C Lead Networks for Servomechanisms; *Donald McDonald* (*University of Michigan, Ann Arbor, Mich.*).

Two general classes of a-c lead networks normally are used when the input and output voltages of a lead network must be modulated, suppressed-carrier voltages. In the first class of a-c lead networks, the signal is demodulated; then the demodulated signal is passed through a conventional d-c lead network; and lastly, the carrier is remodulated with the output voltage of the d-c lead network. The second class of a-c lead networks consists of tuned networks, such as the conventional tuned *RLC* and parallel *T* lead networks.

These two classes of conventional a-c lead networks do not operate on their input signals so effectively as do the conventional d-c lead networks, for the following reasons: The lead produced by the d-c lead network in the first class of a-c lead networks is reduced by the filter circuits used to minimize the noise generated by the demodulator and modulator. Changes in carrier frequency can reduce the effective lead developed by the second class of a-c lead networks and, in some cases, can produce lag instead of lead. The limit on the minimum frequency at which maximum phase lead of the second class of a-c lead network occurs makes it difficult to apply this class of lead network to many servo problems.

These limitations in the performance of the conventional a-c lead network may be minimized for the class *I* network by a rearrangement of the elements of the lead network. For example, consider such a circuit, where the demodulator and modulator filters of the class *I* a-c lead networks are used to an advantage. In this circuit the time delays or phase shifts created by the filters of the demodulator and modulator are lumped together with an adjustable time delay in the single *RC* network. This lumping of time delays, by simplifying the analytical expressions of the circuit, will show that the characteristics of this system are the same as for the conventional class *I* a-c lead network. Here the general approach used in modifying the basic class *I* a-c lead network has been to place all of the elements with negative phase shifts in a feedback branch where they effectively will produce lead instead of lag. By this procedure the inherent and unavoidable delays that occur in many elements, such as demodulators and modulators, can be put to an advantage instead of being a handicap.

The effectiveness of the demodulator and modulator filters, or the complexities of the demodulator and modulator plus filters, may be such as to limit the practical degree of suppression of generated noise. By changing, as well as rearranging the type of components used in the basic class *I* network, a lead network can be evolved having demodulators and modulators with excellent noise-to-signal ratios. These demodulators and modulators are electromechanical components, and therefore such a lead network will be referred to as an electromechanical a-c lead network. Two types of these electromechanical a-c lead networks operate like simple lead networks and resonant lead networks, respectively.

The electromechanical a-c lead networks described do not have the limitations of either the conventional class *I* or class *II* a-c lead networks and therefore may have a broader servomechanism application.

A New Technique in the Manufacture of Soldered Porcelain Potheads; *A. E. Papp, J. H. Nicholas* (*G and W Electric Speciality Company, Chicago, Ill.*).

The advantages of potheads made with metal parts soldered directly to metalized porcelain, over the conventional gasketed assemblies, are numerous particularly when terminating important cables. Soldered porcelain potheads properly installed, from a hermetic seal on the ends of the cable so necessary for satisfactory performance in paper-insulated cables. The earliest soldertite potheads of about 12 years ago, used a solder sealing process developed by a large porcelain manufacturer. The process was found to be satisfactory but rather hard to handle. Because of this difficulty in handling, it was decided to develop a solder seal process that would be easier to handle and could be applied to porcelain made by any manufacturer.

This new process, we believed, should be adaptable to a live range of sizes and shapes of porcelain required by the users of cable terminal equipment. The resultant developed processes and techniques in the manufacture of soldertite potheads, although established empirically, are rigid in their latitude. Time, temperature, and technique must be controlled absolutely, and cleanliness in all operations is a "must." Briefly, the process consists of coating certain areas of a heated, chemically clean, glazed porcelain with molten copper sprayed from a metallizing gun, tinning those areas with solder, and then soldering to a metal part. The completed seal consists really of three bonds or joints in series; the copper-to-porcelain bond is the most difficult to make and requires a great deal of consistency in control. The copper-to-solder bond is easiest to make and requires ordinary care. The solder-to-metal bond is not very difficult to make but it does require manual dexterity and skill that comes only with long practice.

Mechanical design criteria are rigorous but a properly made soldertite joint will remain free from leaks and mechanical and electrical failure after the following tests:

1. Repeated instantaneous thermal shocks from 250 degrees Fahrenheit to −10 degrees Fahrenheit.
2. A frigid test of about four hours at −70 degrees Fahrenheit.
3. Abnormal vibration of both the aerial connection and the pothead base.
4. Repeated severe mechanical shock.

Every soldertite pothead that is produced is tested rigorously in the following manner:

1. The whole structure is jarred severely a number of times by bouncing it severely on a wooden table in a position parallel to the axis of the pothead.
2. Tested at 30 to 40 pounds per square inch air pressure while submerged in a hot water bath at 160–180 degrees Fahrenheit.
3. A complete electrical test of the pothead utilizing a grounded collar on the outside of the porcelain and an insulated probe on the inside of the porcelain at about 15 kv, 60 cycles alternating current in order to detect any cracks or fissures.

A New 69-Kv Oil-Blast Circuit Breaker; *E. B. Rietz, C. J. Balentine* (*General Electric Company, Schenectady, N. Y.*).

During the past ten years, there has been considerable development in higher voltage circuit breakers which has resulted in faster operating times, increased interrupting capacity, and reduced maintenance. These improved operating characteristics were just as desirable at 69 kv and below as in the higher voltage classes. Therefore, a new 69-kv oil-blast circuit breaker has been developed with improved oil-blast interrupters, completely sealed bushings, greater interchangeability of parts between ratings, easier assembly and alignment, simplified operating mechanisms, and increased mechanical life.

The most important of the new features include:

1. The 5-cycle dual-flow cross-blast interrupter.
2. The design of the pole unit structure.

A new dual-flow cross-blast interrupter was developed to give improved interrupting performance and to reduce maintenance. It incorporates the simplicity of the contact arrangement using two sequential arcs, the first generating the oil-blast action to cause interruption at the second. In addition, an insulation baffle structure has been developed which surrounds the pressure generating arc and stabilizes it so that the arc energy liberated was reduced to a minimum. A second baffle arrangement in the region of the interrupting arc directs a dual flow of oil to converge simultaneously from both sides on the arc and sweeps the arc products out at right angles in both directions. The contacts and baffles are housed in a heavy walled insulation tube which is bolted readily to the metallic adapter mounted on the lower end of the bushing, thus making inspection easy. Arc-resistant material on the contact surfaces and the improved interrupter performance result in a minimum of contact and oil deterioration.

The pole unit structure includes smaller diameter tanks to reduce the over-all dimen-

sions and the quantity of oil. The pole unit top frames are simplified welded steel structures with provisions for two bushing-type current transformers per bushing. The bushings utilize the well-known oil-filled type *L* construction with the porcelains soldered to metal fittings to eliminate gaskets. The new smaller circuit breaker is shipped assembled to reduce field installation labor. A pneumatically tripfree compressed air operator provides exceptionally fast reclosing times with minimum power consumption and control connections.

Proof of performance was obtained by extensive design tests in the high-power test laboratory and by field tests. Field tests on the Pennsylvania Power and Light Company system resuled in duties of 1,400 megavolts which confirmed factory design tests. Fault duty cycles of all types were checked in addition to the interrupting performance on line switching. On the fault tests, there were no signs of disturbance. The only indication of circuit breaker operation was the movement of the position indicator. The contacts after 22 fault operations with eight at maximum duty were in excellent condition and could have been used for additional tests. Dropping of 70 miles of line was accomplished promptly and without substantial overvoltages.

The new 69-kv circuit breaker incorporates all of the objectives originally outlines. The design has been proved by tests both in the laboratory and under actual system conditions. Field tests again have demonstrated their value in an over-all program for the development of new circuit breakers.

Development and Testing of an Improved High-Capacity High-Voltage Impulse Circuit Breaker; *E. B. Rietz* (*General Electric Company, Schenectady, N. Y.*).

The unprecedented expansion of transmission systems in the next few years will require circuit breakers having higher interrupting capacity, higher voltage ratings, shorter interrupting times, shorter reclosing times, and elimination of restriking. Of the various types of circuit breakers used at existing voltage and interrupting ratings the low-oil content impulse circuit breaker has the most impressive test and operating record. The first impulse circuit breakers rated at 287.5 kv were described before the Institute in 1935. Subsequently, large numbers of impulse circuit breakers were installed in locations which demanded the utmost in interrupting performance, or where restriking had to be eliminated, or where maintenance or oil handling equipment had to be a minimum.

The characteristics of the impulse circuit breaker which caused it to be selected for development to meet these new requirements were

1. Laboratory tests indicated that interrupting capacities far in excess of any required in the foreseeable future could be designed into it. Field tests on a standard 3,500-megavolt 230-kv circuit breaker up to 6,700 megavolts substantiated this conclusion.

2. The uniform oil-blast action supplied by the mechanically driven piston insured minimum arc durations. Restriking when interrupting line charging currents was eliminated by the positive piston blast.

3. Faster operating and shorter reclosing times could be obtained with less energy because of the shorter contact stroke and lighter weight parts.

Better voltage distribution could be obtained across the series breaks because they were not encased in a grounded steel tank.

5. The smaller quantity of oil over that of a tank circuit breaker reduced maintenance and oil handling equipment, simplifying over-all station design.

The first improved impulse circuit breaker was built for a rating of 360 kv and 10,000 megavolts. After extensive factory tests two units were built to obtain test and operating data under field conditions. The first unit was installed in a complete switching unit on the Tidd high-voltage test line of the American Gas and Electric Service Corporation. The second was given high-capacity field tests at Grand Coulee Dam.

To obtain improved interrupting ability a new interrupting unit was designed to obtain the maximum efficiency from each set of the series-connected contacts and to reduce the loading on the porcelain housings during interruption. By using external grading shields and the optimum spacing of the contacts, the voltage distribution across the breaks was found to be remarkably uniform. Mechanical loading of the porcelain housings became almost negligible when they were supported on the inner herkolite tubes which enclose the interrupting chamber.

To obtain higher speed reclosing a new air-operated mechanism was designed and located directly beneath the vertical column so a straight line connection could be made to the operating rod. Each mechanism is self-contained and operates one pole of the circuit breaker. The elimination of mechanical ties between pole units permitted faster operating times and single-pole operation.

The interrupting tests at Grand Coulee Dam checked the 360-kv circuit breaker design and provided data for the 230-kv 10,000-megavolt circuit breakers for the new switchyard at Grand Coulee Dam. Tests were made with various fault duty cycles and the circuit breaker gave no indication of stress up to the maximum duty available of 8,700 megavolts. All interrupting times were less than three cycles and successful reclosing tests were made down to 8.5 cycles. Contacts and oil were in excellent condition at the conclusion of the series. Switching of up to 382 miles of line was accomplished without restriking or objectionable overvoltages. In conjunction with laboratory tests these field tests gave ample evidence that impulse circuit breakers will meet all the requirements for circuit breakers of higher interrupting capacities at existing voltages and for higher voltages.

Synchronized Microtime Photographic Techniques; *A. M. Zarem* (*Stanford Research Institute, Los Angeles, Calif.*).

The increased tempo of scientific activity during the last few years has resulted in a growing need for photographic techniques to obtain ultrashort (submicrosecond) exposure times. This steadily advancing interest in the photography of very high-speed phenomena and the need for investigation of physical phenomena of a transient nature also have highlighted the problem of synchronization of the camera shutter with the phenomena under study.

When submicrosecond photographic exposure times are required, one is obliged to seek new methods, since both mechanical means and flashlamp techniques have not yet been commercially developed to be effective for this range. The electro-optical (Kerr cell) shutter in which there are no moving parts represents a very attractive and novel method for obtaining submicrosecond photographic exposure times. With such a Kerr cell camera photographs with an effective exposure time of 1/100 of a millionth (0.000,000,000,01) of a second have been obtained successfully. The use of several shutters pulsed in sequence is suggested for obtaining rapid photographic rates. Using a multiple Kerr cell camera it has been found that photographs can be taken at extremely short intervals corresponding to a framing rate of 100 million exposures per second.

The problems which arise in the construction and operation of Kerr cell cameras lend themselves in many cases to rather simple solutions. Electric circuitry required for the operation of the shutter and for synchronization with other phenomena is rather simple, requiring only a small number of tubes. Although high voltages are required for shutters of wide aperture, the use of radio-frequency power supplies insures that all elements of the Kerr cell camera, including the auxiliary equipment, can be made quite rugged and lightweight. It appears that a compact Kerr cell camera unit will be commercially available soon.

With the advent of the "all-electric shutter" further techniques of the electric art become applicable to photographic work.

A Subminiature Tube Application; *W. W. Snyder* (*Physics Laboratories, Sylvania Electric Products Inc., New York, N. Y.*).

The subminiature decade ring counter for electronic computers measures only 2 inches by $2^1/_2$ inches over-all, and compactness was made possible through the use of subminiature tubes. Each unit, designed to be plugged into a computer, in the same manner that radio tubes are placed in broadcast receivers, includes 11 subminiature thyratron tubes, 80 resistors, and 23 capacitors.

The ring counter is subdivided into 11 sections, each attached to a ceramic card on which the wiring is printed to connect a subminiature thyratron, seven resistors, and two or three capacitors. The 11 ceramic cards are arranged in a circle and attached to a standard plug-in base.

During operation in an electronic computer, the counter has ten stable states corresponding to conduction by one of the ten thyratrons. Signal pulses applied to the counter render the thyratrons progressively conductive.

Traverse Drives for Rayon Spinning Frames; *H. I. Kintz, R. R. Prechter* (*General Electric Company, Schenectady, N. Y.*).

In the cap spinning and bucket spinning methods of the acetate and viscose rayon processes, respectively, traverse drives perform the important function of moving the traverse rail of the spinning frame back and forth in a straight line in accordance with a predetermined program. These drives are important since they determine the shape of the yarn packages produced by the spinning frame.

Two new types of traverse drives have been developed for use on a rayon cap spinning frame, on which the traverse rail weighed approximately 4,000 pounds and traverse frequency was two cycles per second, and

consisted of an electronic-amplidyne generator traverse drive in which the rotary motion of a motor is converted into linear motion of the traverse rail, and an hydraulic traverse drive in which the required straight line motion is secured directly from a power piston. These drives are servo systems in which the position of the traverse rail corresponds to the position of a small light control cam.

Of the two drives developed the hydraulic drive has proved to be the most successful with reversal times of 1/17 of a second being secured easily.

Successful laboratory results have been secured with a high-speed hydraulic traverse drive suitable for use on viscose rayon spinning machines. A weight of approximately 300 pounds was traversed over a stroke of approximately six inches and with traverse frequencies from 0 to 60 cycles per minute.

From our experience to date on traverse drives suitable for rayon spinning machines, it may be concluded that the hydraulic drive offers the following advantages when compared to conventional mechanical drives (power cam, gearing, and linkage system):

1. Straight-line motion is a natural product of the hydraulic piston, while conventional drives must convert from rotary to linear motion with greater backlash problems.

2. Faster traverse speeds and reversals are possible due to low-inertia parts of the hydraulic system.

3. Less maintenance should be secured, because wearing surfaces are not subjected to direct power transmission since the piston provides the direct power thrust.

4. High sustained accuracy can be obtained with the single-stage hydraulic servo drive.

5. The hydraulic drive allows quick changes in traverse program by easy cam change.

6. The hydraulic drive can be packaged easily as one totally enclosed unit. This is of decided advantage in acetate spinning where possibility of explosive acetone concentrations exist, or in viscose spinning where the sulpheric atmosphere vigorously attacks exposed surfaces.

Transformations Useful in Constructing Analogs of Linear Vibration Problems; *James Phillip Corbett (Northwestern University, Evanston, Ill.).*

This paper is concerned with the problem of realizing arbitrary linear systems of vibrations in terms of electric circuits. The system under study is represented by a system of ordinary differential equations, linear, with constant coefficients. Such a system has an electric circuit representation if the vibrations are of stable type. However, the realization may require the use of ideal transformers, ideal unilateral impedances, and the number of such devices may be excessive. Again, the realization may require an excessive range of impedance values or may require linear behavior over too great a range of frequencies.

Difficulties arising from frequency requirements usually can be evaded by changes of time scale which compress the frequency range. Difficulties concerning the numerical ranges of impedance elements, for example capacitors, generally are eliminated by a combination of a change of time scale and a change of scale of current or charge.

In standard works it is shown that a system of linear differential equations with constant coefficients can be reduced to a triangular system by use of a system of multipliers with constant determinant. The use of a transformation of this type can result in considerable simplification. It is possible to alter the essential type of coupling appearing between loops of the circuits by this means. This transformation is particularly valuable since it does not alter the dependent or independent variables, and introduces only rational functions of the original parameters.

If the original system is expressed in terms of operators it appears as an ordinary system of linear algebraic equations. In matrix form, this last transformation is simply a multiplication of this system on the left by a nonsingular matrix of constant determinant, that is a set of row transformations of the original matrix. A corresponding column transformation of the system can be made, multiplication on the right by a nonsingular matrix of constant determinant. This transformation introduces new dependent variables, but there are cases in which this transformation can be kept sufficiently simple for practical use. By the use of the foregoing transformations many systems which otherwise would be difficult or unwieldy are found to have simple passive representations.

A simple treatment of changes of independent variable for a general differential equation may be given. Here the defining relationship among the derivatives may have simple discontinuities. The importance of this lies in emphasizing the way in which initial conditions are transformed. When the system to be analoged contains a nonlinear element or a simple discontinuity the realization of initial or boundary conditions in the analog must be given careful attention. Even for linear systems there is always the possibility of obtaining simplification in the analog through attention to the realization of a suitable set of initial conditions.

Compact Radiographic Tubehead Using Forced Oil Cooling; *S. Gilman (formerly with Westinghouse Electric Corporation, Bloomfield, N. J.), J. Lempert (Westinghouse Electric Corporation, Bloomfield, N. J.).*

The conventional radiographic X-ray tubehead relies on natural convection cooling to transfer heat from the tube to the insulating oil which surrounds it, and from the oil to the metal walls of the head. Natural thermal convection currents are generally effective in instances of favorable geometry. However, they have proved to be inadequate for dissipating high loading in X-ray tubeheads, and unfavorable geometry and the necessity for operating the head in all positions have resulted in "hot-spotting" of a serious nature. The problem is particularly pertinent today because recent radiographic techniques, such as mass chest survey photoroentgen work and spot film fluoroscopy, have increased maximum average loading requirements from some 100 watts continuous to 400 or 500 watts continuous. The "hot spotting" in the tubehead offers serious limitations to the life of the tube and head. Excessive local temperatures result in deterioration of the insulating oil and of other organic components of the tubehead, such as the insulating sockets and the tubehead window. Also, lack of adequate oil circulation may cause the tube to overheat, increasing the probability of the tube gassing up, and producing oil carbonization at the interface between the tube radiator rod and the oil, which progressively decreases the cooling efficiency.

An improved tubehead design cools the anode directly with a stream of oil and also circulates the oil through the tubehead. This method of cooling not only results in substantial lowering of anode temperature, but also eliminates "hot spots" in the head. In addition to more uniform temperatures, better efficiency of heat transfer from the tubehead to the surrounding air is achieved by bringing up the temperature of those parts which previously dissipated negligible heat. The multibenefits of forced oil flow to the anode are recognized.

Flame Detectors for Domestic Fuel Burner Safety Devices; *Justin A. Deubel (Perfex Corporation, Milwaukee, Wis.).*

Perhaps the most essential component part of a safety combustion control for domestic fuel burners is the flame detector.

The flame detector serves to determine whether or not proper combustion is taking place and to introduce this intelligence electrically into the combustion control circuit. This enables the control circuit to perform prescribed functions corresponding to the flame conditions. One of these prescribed functions is to shut the burner down subject to manual reset in the event flame is not properly established or becomes extinguished after it is satisfactorily established.

Flame detectors may be segregated into four types:

1. Those responding to the temperature of the products of combustion.

2. Those responding to the total radiant energy of the flame.

3. Those responding primarily to the luminous radiation of the flame.

4. Those responding to the electric conduction of the flame.

The first group is the form most customarily used. It consists primarily of a temperature-sensitive element having mechanical motion as a result of the differential expansion of two dissimilar metals. This motion is coupled through a "slip friction" device to operate an electric switch or switches on *change* in temperature.

The third group responds practically instantaneously to flame condition and thus permits the combustion control to return electric ignition on flame failure without providing a scavenging time to purge the system of unburned vaporized fuel. This scavenging time is essential when group 1 and 2 controls are used because the greater response time permits the burner to run some few seconds delivering unburned fuel before the fact that the flame has been extinguished becomes known.

The group 4 detectors have the same response time advantage as group 3 but are not generally suited to oil flames because of the deleterious effect of the oil flame on the electrode and the failing of the flame rod insulator due to dirty products of combustion.

The same form of amplifier and relay may be used for both group 3 and 4 detectors, since both flame and photocell are high-impedance rectifiers whose effective impedance changes in the presence or absence of flame. In one form of amplifier, the resultant charge of a capacitor due to thyratron grid current and photocell or flame anode current, is used to determine the grid tripping voltage of a thyratron. The thyratron in turn operates an electromagnetic relay in response to the flame condition.

INSTITUTE ACTIVITIES

The Publications of Our Institute

—*A Message From the President*

The publications of our Institute are another of the great strengths of our Institute. When we say publications we mean:

ELECTRICAL ENGINEERING

Preprints of Institute papers

PROCEEDINGS of Institute papers

TRANSACTIONS of Institute papers

Standards

Recommended practices, specifications, and reports

The amounts we expend are ever-increasing, as Table I reveals.

These increasing amounts reflect the growth of our Institute and our broadening Institute activities. They also reflect increasing costs which have been considerable and which we have been able to assume, but which are requiring our increasing consideration.

ELECTRICAL ENGINEERING is the magazine of our Institute. It carries the message of electrical engineering everywhere in the electrical engineering field. The circulation of the March 1949 issue was 50,600 copies as follows:

To our members in United States, Canada, and Mexico	30,000
To our members abroad	1,350
To our Student Members	16,850
To librarians and other subscribers in the United States	900
To librarians and other subscribers abroad	1,500
Total	50,600

These figures are of most powerful significance for they show that the message of electrical engineering progress and technical achievement is being carried to all the world.

Any member of our Institute can submit a paper describing his contributions to the advancement of electrical engineering for consideration by his fellow members for publication. Where such papers are scheduled for presentation at a District or general meeting of our Institute, they are preprinted to be available for such presentation and for discussion thereof. Each member learns of these through the meeting announcements and through *ELECTRICAL ENGINEERING*. There thus is made available to everyone, quickly, the understanding of every new advance in electrical engineering which our members will describe. This is a great strength. We have budgeted for this year the printing of 124,000 preprints at a cost of $25,000. The charge for these is budgeted to return $20,000 of this cost. This strength of our Institute is being used by several thousand of our membership. This is an outstanding contribution. We extend publication privileges to nonmembers also under appropriate circumstances.

Everett S. Lee

After presentation and with discussion, the preprinted papers are printed with discussion as *PROCEEDINGS* papers for distribution to our membership for those who request them by using the order form regularly printed in *ELECTRICAL ENGINEERING*. Up to ten per cent of all papers are allowed each member of our Institute without charge.

At the end of each year the *PROCEEDINGS* papers are bound into the annual *TRANSACTIONS*. There is an extra charge for these. Some 1,250 of our members purchase these, and some 700 copies are purchased by libraries and other groups. Herein resides the permanent record of the electrical engineering contributions of the years. Our *TRANSACTIONS* are available for reference since the year 1884. No one ever can visualize the power of this reservoir of knowledge. That it represents the advance of electricity into every avenue of service for all mankind attests to its magnitude and scope beyond all comprehension, beyond all description. Yet there it is for all of us to have and to use and to continue to contribute to it that it may be forever virile.

The control of the electrical industry is in its standards. To these our members have contributed throughout our Institute life of 65 years. To our Institute is entrusted the fundamentals. Our expenditures for Standards publication have been a substantial part, and together with specifications and reports, they represent a service which could not be obtained in any other way.

For all of these publications we owe outstanding recognition to our committees which progress these—which are the publication committee, the technical program committee, all of our technical committees, the Standards committee, together with our editor of *ELECTRICAL ENGINEERING* and his staff.

To include completely the ever-broadening base of electrical engineering achievement and accomplishment, we always have maintained our Institute committee organization appropriate to the services to be rendered. With the recent organization of our technical committees into groups, there comes the opportunity for making available by groups the technical papers as they are presented. This same availability is present now in our *PROCEEDINGS* arrangement though it seems not to be used to its potential. If our members who desire the new papers quickly would take a little time to check the free paper lists (*PROCEEDINGS* order forms) carried in *ELECTRICAL ENGINEERING*, the usefulness of this available service would be considerably enlarged. This is a service designed to have a minimum of waste as the papers go only to those who ask. In these days when every dollar counts, this is a prime consideration which should appeal to our members as good management, which has been our continual aim.

When one gives some time to think of our enormous coverage in the electrical engineering field and of the multiplicity of our member interests, our publication structure and output to serve them and to provide for them to serve their fellowmen is seen to be an outstanding strength, the more intimate study of which reveals the more that it is a powerhouse for great good. Every member should use it to recognize it as such.

Table I

Publication	Expended 1944–45	1945–46	1946–47	1947–48	Appropriated 1948–49
ELECTRICAL ENGINEERING (text)	$77,446	$99,518	$138,524	$167,381	$177,615
Preprints	9,122	13,785	17,806	22,812	25,000
PROCEEDINGS			16,449	33,871	32,375
TRANSACTIONS	15,240	6,845	11,210	11,193	20,200
Standards, specifications, and reports	19,000	17,000	18,280	19,335	27,300

AIEE Publications Services Reviewed for Membership

The publications of the Institute are designed to advance effectively the theory and practice of electrical engineering and the allied arts at minimum cost to members. The electrical industry today is highly specialized. To attempt to distribute all of the technical papers in specialized fields to a large membership would not only be prohibitive but wasteful and inefficient. With these views in mind, each of the different types of publications has been planned carefully to bring the most useful material to the greatest number of members. To enhance the usefulness of the service, each publication is reviewed briefly in respect to content and objective together with a statement telling how it may be procured. For those interested in greater detail the publication policy now in effect was announced in *ELECTRICAL ENGINEERING* for December 1946, pages 576–8. Reprints of the policy are available on request.

ELECTRICAL ENGINEERING

This is the official monthly publication of the Institute which is distributed automatically to all members and Student Members in good standing. The text matter consists of general interest articles, timely technical papers of broad interest, and one page digests of all technical papers. Thus with a yearly technical program of 250 papers, *ELECTRICAL ENGINEERING* carries about 30 per cent of them. By judicious selection of the 10 per cent free allowance of AIEE *PROCEEDINGS* (to be described later), using the one page digests as a guide, it is possible for a member to obtain about 40 per cent of the technical papers without charge. In the interest of complete coverage many conference papers are included which are not available elsewhere, as well as abstracts of many others. Sections on "Institute Activities" and "Of Current Interest" contain meeting programs and reports, membership data, personals, and news of the principal activities within the Institute each month as well as news of the electrical industry in general.

With a circulation of more than 50,000, *ELECTRICAL ENGINEERING* also is available by subscription sent directly to Institute headquarters at an annual rate of $12 payable in advance (plus $1 extra for foreign postage payable in advance in New York exchange). A discount of 25 per cent is allowed to college and public libraries. Publishers and subscription agencies may be allowed a discount of 15 per cent.

AIEE PROCEEDINGS

As an interim service to specialists (until the annual *TRANSACTIONS* is available), the full text of all technical papers correlated with discussion, if any, as approved for publication in the *TRANSACTIONS* are made available to members only. Ten per cent of the papers are free to members and additional papers are available at ten cents each. In the case of Student Members there is no free allowance. *PROCEEDINGS* must be ordered in the manner prescribed on order forms which appear in the advertising section of *ELECTRICAL ENGINEERING* every few months. The location of order forms of papers still available is given on the "Highlights" page (*3A*) each month.

AIEE TRANSACTIONS

The full text of all technical papers and related discussions, as approved by the technical program committee, which were presented at the general and District meetings, are bound in an annual cloth volume for ready reference. To reduce bulk and make half of the papers available sooner, volume 67 for 1948 is issued in two parts. Part I contains the papers for the first half of the year and was made available last fall. Part II, containing the papers for the remainder of the year, will be available this spring. *TRANSACTIONS* are available to members by advance subscription to AIEE Order Department at a price of $5 per year. Nonmember advance subscriptions are $12 payable in advance (plus $1 extra for foreign postage payable in advance in New York exchange). A discount of 25 per cent is allowed to college and public libraries. Publishers and subscription agencies may be allowed a discount of 15 per cent. An advance reservation form for the 1949 *TRANSACTIONS* will appear in the "Highlights" or advertising section of a subsequent issue of *ELECTRICAL ENGINEERING*

Combination advance subscription to *ELECTRICAL ENGINEERING* and *TRANSACTIONS* on a concurrent calendar-year basis to a single addressee is $16 per year payable in advance (plus $2 extra for foreign postage payable in advance in New York exchange).

ANNUAL INDEXES

A complete annual index to *ELECTRICAL ENGINEERING* is published each year as section 2 of the January issue and it is distributed with that issue. An annual index to the *TRANSACTIONS* is published each year and bound in the back of the annual volume. These indexes are arranged alphabetically by subject and by author.

Cumulative indexes to *TRANSACTIONS* have been published from time to time. Volume 1 (1884 to 1900) and volume 2 (1901 to 1910) are out of print. With the purchase of volume 4 (1922 to 1938), priced at $2 to members ($3 to nonmembers), a copy of volume 3 (1911 to 1921) will be included.

AIEE SPECIAL PUBLICATIONS

To meet a specialized need, or where it becomes advantageous to collate a number of papers on a subject in one pamphlet, a series of special publications has been established. In some cases these special publications may consist of reprints of papers from *ELECTRICAL ENGINEERING*, special committee projects, bibliographies, or highly mathematical treatises which are not appropriate for magazine publication. These special publications are of various lengths; published on an entirely self-supporting basis at cost to members and, in general, at double the cost to nonmembers.

A listing of AIEE special publications is in this issue of *ELECTRICAL ENGINEERING* (page 60A of the advertising section). Subsequent publications, as they become available, will be announced in the "Institute Activities" sections or on the "Highlights" page. Remittances and orders should be sent to the AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

PREPRINTS AND REPRINTS

To encourage and facilitate discussion of technical papers, preprints are made available by a photolithographic process. A few papers which are of timely interest, but not of permanent-record value, are made available as miscellaneous papers on an advance copy only basis. For the purposes of discussion, 10 copies are given to authors free, and an average of 25 copies is made available to the sponsoring committee. Preprints are sold to members at a price of 30 cents each, and to nonmembers at 60 cents each. For convenience, order forms with paper numbers are mailed with the announcements of general and District meetings, and members not receiving an

Future AIEE Meetings

AIEE Conference on Industrial Application of Electron Tubes
Statler Hotel, Buffalo, N. Y.
April 11–12, 1949

South West District Meeting
Baker Hotel, Dallas, Tex.
April 19–21, 1949
(*Final date for submitting papers—closed*)

AIEE Conference on Rubber and Plastics Industries
Portage Hotel, Akron, Ohio
April 26, 1949

AIEE Conference on Materials Handling
Hotel Cleveland, Cleveland, Ohio
May 13, 1949

AIEE Conference on the Textile Industry
Massachusetts Institute of Technology, Cambridge, Mass.
May 3, 1949

AIEE Conference on the Textile Industry
Georgia School of Technology, Atlanta, Ga.
May 26–27, 1949

Summer General Meeting
New Ocean House, Swampscott, Mass.
June 20–24, 1949
(*Final date for submitting papers—closed*)

Pacific General Meeting
Fairmont Hotel, San Francisco, Calif.
August 23–26, 1949
(*Final date for submitting papers—May 25*)

Midwest General Meeting
Netherland Plaza Hotel, Cincinnati, Ohio
October 17–21, 1949
(*Final date for submitting papers—July 19*)

Winter General Meeting
New York, N. Y.
January 30–February 3, 1950
(*Final date for submitting papers—November 1*)

announcement may order copies from the paper numbers which appear in the programs as they are announced in *ELECTRICAL ENGINEERING*. Remittances and orders should be sent to the AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

As a special service, reprints are available to authors of articles in *ELECTRICAL ENGINEERING* as well as of technical papers in the *TRANSACTIONS*, provided orders are received in advance of going to press. Prices are quoted to author's when the galley proofs are sent on an at-cost basis plus a reasonable percentage for handling.

STANDARDS

The Standards publications of the AIEE are devoted chiefly to defining terms, conditions, and limits which characterize behavior of electric machines and apparatus, with special reference to acceptance tests. There are two categories, approved Standards (and Test Codes) and Reports; the former bear full approval of the AIEE, while the latter are proposals in the formulative stages which are published for comment received as the result of practical experience in their use. In addition to the foregoing, the Institute sells, for the convenience of its members, certain American Standards to which the Institute contributed and in which it collaborated through its representatives and which are approved by the American Standards Association.

A listing of the titles and prices of the Standards sold by the AIEE is available upon request to the AIEE Order Department, 33 West 39th Street, New York 18, N. Y., and is published from time to time in the advertising section of *ELECTRICAL ENGINEERING*. The latest list of Standards appears in this issue (*page 36A*) and the list of Reports is in the February 1949 issue (*page 40A*). Also, as new or revised publications are issued notice is always given in an issue of *ELECTRICAL ENGINEERING*.

AIEE YEAR BOOK

The Year Book contains a roster of Institute members arranged in two sections: an alphabetical index giving the name of each member and the city of his membership registry; a catalogue of the membership subdivided geographically and arranged alphabetically within each subdivision. Included also is a listing of AIEE officers for the current Institute year, the personnel of all committees, general information, the constitution and bylaws. Any member may obtain a copy of the Year Book by addressing a request to Institute headquarters.

REPORT OF BOARD OF DIRECTORS

The annual report of the board of directors for the fiscal year ending April 30 usually is made available in pamphlet form for the annual meeting held in June. The annual report includes a brief summary of each of the meetings held during the previous fiscal year as well as brief reports of the various committees and a financial statement prepared by the auditors. The annual report of the board of directors for the fiscal year ending April 30, 1948, was published in *ELECTRICAL ENGINEERING* for August 1948, and will be published in the annual volume of the AIEE *TRANSACTIONS*. A pamphlet copy may be obtained by addressing a request to Institute headquarters at 33 West 39th Street, New York, N. Y.

INFORMATION FOR AUTHORS

For the guidance of authors and contributors, the Institute has a booklet entitled "Information for Authors." The booklet contains helpful information for the preparation of manuscripts and illustrations; for the presentation of papers at meetings as well as for articles to be prepared for *ELECTRICAL ENGINEERING*. Prospective authors of papers for presentation at meetings should direct requests for a copy of the booklet to the Secretary of the Technical Program Committee, American Institute of Electrical Engineers, 33 West 39th Street, New York 18, N. Y. Prospective contributors of articles for *ELECTRICAL ENGINEERING* should direct requests for the booklet to The Editor, *ELECTRICAL ENGINEERING*, AIEE Publications Department, Suite 7–8 Lower Level, 500 Fifth Avenue, New York 18, N. Y. Copies of the booklet in quantity for writing or classroom purposes may be purchased from Institute headquarters at a price of 30 cents each.

Interesting Program Organized for Electron Tube Conference

Plans have been completed for the AIEE conference on the industrial application of electron tubes to be held at the Statler Hotel in Buffalo, N. Y., April 11–12, 1949. The conference is sponsored by the AIEE subcommittee on electron tubes of the electronic committee and the subcommittee on electronic control of the industrial control committee, jointly with the AIEE Niagara Frontier Section.

The purpose of the present electron tube conference is to provide an opportunity to discuss the application of electron tubes in the industrial field. Papers will be presented and discussion will be encouraged among an audience of persons primarily interested in applying and operating tubes in industrial equipment. The program has been planned to cover experiences of the users and designers of equipment utilizing electron tubes, as

Conference Program

Industrial Application of Electron Tubes

Monday, April 11

8:30 a.m. Registration—Statler Hotel

9:30 a.m. Opening Meeting—Ballroom

Welcome. J. E. Sowers, chairman, Niagara Frontier Section

Opening remarks. H. L. Palmer, conference cochairman

Review of 1948 conference on electronic tubes for instrumentation. J. G. Reed, Jr., chairman, joint subcommittee on electronic instruments

9:30 a.m. Industrial Electronic Control Applications

Presiding: W. C. White, General Electric Company, Schenectady, N. Y.

Electronic Control of D-C Motors. *Ben Cooper*, General Electric Company, Schenectady, N. Y.

Electronic Regulators and Regulating Systems. *W. G. Roman*, Westinghouse Electric Corporation, Buffalo, N. Y.

Electronic Control of A-C Power. *E. W. Hutton*, General Electric Company, Schenectady, N. Y.

Electronic Relaying Devices and Photoelectric Control. *F. T. Bailey*, Westinghouse Electric Corporation, Buffalo, N. Y.

12:00 Noon. Luncheon—Ballroom

1:30 p.m. Inspection Trip of Westinghouse Plant

6:30 p.m. Dinner—Ballroom

Address on "Control Aspects of Atomic Power," K. H. Kingdon, assistant director of the General Electric Research Laboratory in charge of the Knolls Atomic Power Laboratory

8:30 p.m. Problems of Electronic Equipment Users—Ballroom

Presiding: J. A. Gienger, Eastman Kodak Company, Rochester, N. Y.

Effects and Need of Primary Voltage Control. *Frank J. Hosticka*, Visking Corporation, Chicago, Ill.

Additional papers pertaining to the problems of users of electronic control equipment are being organized with speakers from representative industries.

Tuesday, April 12

9:00 a.m. Problems of Electronic Equipment Design—Niagara Room

Presiding: H. L. Palmer, General Electric Company, Schenectady, N. Y.

Tube Ratings as Applied to Industrial Control Equipment. *O. W. Livingston*, General Electric Company, Schenectady, N. Y.

Desirable Improvements in Tube Characteristics and Ratings. *E. H. Vedder*, Westinghouse Electric Corporation, Buffalo, N. Y.

Problems Related to Components Used in Industrial Electronic Equipment Design. *Rolland Russo*, Clark Controller, Cleveland, Ohio

Selection and Use of Capacitors in Electronic Control Equipment. *W. J. Thacker*, General Electric Company, Pittsfield, Mass.

12:00 Noon. Luncheon—Niagara Room

1:30 p.m. Problems of the Tube Designer—Niagara Room

Presiding: Professor C. H. Willis, Princeton University, Princeton, N. J.

Rating of Ignitrons for A-C Control. *D. E. Marshall* Westinghouse Electric Corporation, Bloomfield, N. J.

Ratings of Ignitrons for Rectification. *H. C. Steiner*, General Electric Company, Schenectady, N. Y.

Ratings of Mercury Thyratrons. *H. L. Thorson*, General Electric Company, Schenectady, N. Y.

Ratings of Inert Gas Tubes. *D. V. Edwards*, Electrons, Inc., Newark, N. J.

Ratings of Radio Receiving Type Tubes. *George Hanchett*, Radio Corporation of America, Harrison, N. J.

Phototube Characteristics. *A. M. Glover*, Radio Corporation of America, Lancaster, Pa.

Closing comments by H. C. Steiner, conference cochairman

well as by those responsible for designing and rating industrial electron tubes.

Registration in advance is requested; those who have not already received the necessary registration blanks may obtain them from V. A. Leitzke, General Electric Company, 535 Washington Street, Buffalo 3, N. Y. The registration fee is $3 for members and nonmembers alike. Rooms will be available at the Statler Hotel for those who register early enough.

As an inspection trip, a guided tour will be made of the new Westinghouse Electric Corporation motor and control plant in Buffalo. A portion of this control division is devoted to the manufacture of industrial electronic controls. Other activities include luncheons on Monday and Tuesday, for which reservations must be made, and a dinner meeting on Monday evening which will feature an address on "Control Aspects of Atomic Power," by Doctor K. H. Kingdon, of the General Electric Company. This will be followed by a regular technical session for electronic equipment users.

Complete transcripts of the technical papers and written discussions will be published as "Conference Proceedings." Copies may be ordered in advance on the registration form, or at the conference, at $3.50 per copy.

Will Rogers Memorial Auditorium and Coliseum in Fort Worth, Tex., sister city to Dallas, South West District meeting host city

Final Arrangements Announced for South West District Meeting

Dallas, Tex., with the aid of its sister city, Fort Worth, is all set to play host to the AIEE South West District meeting to be held April 19–21, 1949. The program for this meeting has been designed along broad lines so as to be of interest to everyone in the great Southwest. The meeting will open with a luncheon on Tuesday at which the story of the economic growth of the Southwest will be told. On Thursday morning, a general session will be devoted to the electrical engineers' contributions to this growth. It is expected that both of these features will be of broad interest, not only to members of the Institute, but to the general public as well.

In so far as possible, technical papers have been prepared by and will be presented by members of the Institute residing in the South West District. The number of papers per technical session has been limited so that each author may present his paper in full and allow some time for discussion. A complete program appears on page 351.

Most of the general arrangements for the 1949 South West District meeting were covered in *ELECTRICAL ENGINEERING* for March (*pages 258–9*). However, additional details have been received since.

An important Texas industry is represented by this Magnolia Petroleum Company oil well which is shown being pumped electrically

INSPECTION TRIPS

As previously noted, trips have been planned for Tuesday, Wednesday, and Thursday afternoons to industries and points of interest in Dallas and Forth Worth. One afternoon trip will include a visit to the Haskell toll office of the Bell system. An afternoon tour to Fort Worth will be made to inspect the new Handley power station of the Texas Electric Service Company, and on the same trip a visit will be made to the new *WBAP-TV* television transmitter and studio. A third trip is scheduled to include the new *Dallas Morning News* building and press room just completed, the most modern and largest plant of its type in the South. Other plants scheduled include a plastics manufacturing plant and geophysical and oil research laboratories.

A small charge will be made to cover cost of transportation on each trip. Costs, dates, and other details available upon arrival.

HOTEL RESERVATIONS

Those who will attend the meeting should make reservations directly with hotels, pointing out that they will be attending the AIEE meeting. A copy of each letter requesting reservations should be sent to George A. Smith, 610 N. Akard Street, Dallas 1, Tex.

The Baker Hotel has been designated as headquarters for the meeting; rooms have been set aside for the members. Rates are

Single rooms	$3.50 to $7.00
Double rooms, with double bed	6.00 to 9.00
Double rooms with twin beds	6.50 to 12.00

Tentative Program

South West District Meeting, Dallas, Tex., April 19-21, 1949

Monday, April 18

7:30 p.m. Registration

Tuesday, April 19

8:00 a.m. Registration

9:30 a.m. General Session

George N. Pingree, presiding

Introductory: Elgin B. Robertson, general chairman

"Our Institute": Everett S. Lee, president

"The Significance of Electrical Activity in Crystal Structure": Doctor Jack T. Wilson, physicist, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

12:15 p.m. Luncheon

J. B. Thomas, presiding

"Economic Development of the Southwest": John F. Falvey, Consultant in Public Utility Relations—Financial and Public, New York, N. Y.

2:00 p.m. Student Session

F. W. Tatum, presiding

2:00 p.m. Inspection Trips

2:00 p.m. Transmission and Distribution

M. H. Lovelady, presiding

DP.* Aerial Cable on Secondary Network. *T. D. Thomas*, Texas Power and Light Company, Dallas, Tex.

DP.* The Design and Construction of Transmission Structures. *Ralph G. Terk*, Hughes Brothers, Inc.

DP.* Installation of a 138-Kv Oil Pipe Cable. Colored movie shown by *R. J. Foley*, City Public Service Board, San Antonio, Tex.

49-10. Distribution Transformer and Secondary Conductor Economics. *Bryce Brady*, Oklahoma Gas and Electric Company

6:00 p.m. Smoker and Buffet Supper

Wednesday, April 20

9:00 a.m. Communication

Lee M. Hartwell, presiding

DP.* A New 3-Channel Stackable Carrier Telephone System. *D. G. Clifford*, Lenkurt Electric Company

DP.* Coaxial Cable Engineering and Construction. *W. E. Haywood*, American Telephone and Telegraph Company

DP.* A New Alarm and Control System for Unattended Coaxial Repeater Stations. *M. P. Brown*, American Telephone and Telegraph Company

9:00 a.m. Usage of Electric Power by Heavy Industry

D. H. Levy, presiding

49-121. Performance of Diesel-Electric Rig for Deep Well Drilling. *E. C. Clark*, General Electric Company; *B. L. Moore*, Humble Oil and Refining Company

DP.* Out of the Texas Woods for News. *I. T. Hockaday*, General Electric Company

DP.* The Need of Lightning Protection for Rotating Electric Prime Movers in Pipe Line Stations. *Ralph Paden*, Atlantic Pipe Line Company

49-124 ACO. Electrolytic Zinc Plant of the American Smelting and Refining Company at Corpus Christi, Tex.** *J. S. Bowman*, American Smelting and Refining Company

9:00 a.m. Student Session

Caruth Building Auditorium, Southern Methodist University

Paul C. Petty, presiding

9:30 a.m. Meeting of Board of Directors

12:15 p.m. Luncheon Honoring Board of Directors

Roof Garden, Adolphus Hotel

2:00 p.m. Meeting of Board of Directors (continued)

2:00 p.m. Relays and Protective Devices

Gordon W. Gerell, presiding

49-125-ACO. Automatic Reclosing of Transmission Lines Without Ultrahigh Speed.** *R. A. Larner*, Texas Electric Service Company

DP.* Distribution Line Protection-Fuses and Relay Co-ordination. *J. P. Barron*, Dallas Power and Light Company

DP.* Report of the Protective Relay Engineers' Conference. *L. M. Haupt*, Texas Agricultural and Mechanical College

49-122-ACO. Relaying of Ring Bus Substations on the Oklahoma Gas and Electric Company System.** *G. E. Brooks*, Oklahoma Gas and Electric Company

DP.* Distance Carrier Current Relaying. *A. J. Nicholson*, Kansas City Power and Light Company

2:00 p.m. Power Generation

Otis Howard, presiding

49-126-ACO. Pumped Storage Installation.** *G. E. Schmitt*, Lower Colorado River Authority

DP.* The Combustion Gas Turbine and Its Application as a Prime Mover for the Generation of Electric Power, and Other Uses. *B. G. Hatch*, General Electric Company

DP.* Latest Experiences with the Cyclone Furnace. *F. G. Ely*, The Babcock and Wilcox Company

DP.* The Design and Construction of the Tacubaya Diesel Plant, Mexico City. *J. K. Jennings*, Mexican Light and Power Company, Limited

2:00 p.m. Inspection Trips

7:00 p.m. Banquet and Dance

Crystal Ballroom, Baker Hotel

Al Jones, toastmaster

Thursday, April 21

9:00 a.m. General Session

John W. Carpenter, presiding

Symposium: "The Electrical Engineers' Contribution to the Growth of the Southwest"

1. For the Electrical Utilities, George L. McGregor, president, Dallas Power and Light Company, Dallas, Tex.

2. For the Communication Companies, H. R. Fritz, chief engineer, Southwestern Bell Telephone Company, St. Louis, Mo.

3. For Heavy Industry, G. R. Walton, United Gas Pipe Line Company, Houston, Tex.

4. For the Manufacturers, W. J. Donald, managing director of National Electrical Manufacturers Association, New York, N. Y.

5. For Educational Institutions, Doctor Umphrey Lee, president, Southern Methodist University, Dallas, Tex.

2:00 p.m. Transmission and Distribution

Norman Rode, presiding

DP.* Experience With Insulating Oils From the Utilities Viewpoint. *D. D. Clark*, Kansas City Power and Light Company

DP.* Phase Reversal and Overvoltages Resulting From Open Conductors in Circuits With and Without Capacitors. *Edith Clarke, A. R. Teasdale, Jr.*, University of Texas

49-123. The Vector Power Factor of Unbalanced Sinusoidal 3-Phase Circuits. *Professor J. F. Lamb*, University of Missouri; *D. B. Brandt*, General Electric Company

49-127. The Negative-Sequence Reactances of an Ideal Synchronous Machine. *William C. Duesterhoeft*, University of Texas

2:00 p.m. Nucleonics

Doctor Jack T. Wilson, presiding

DP.* Radioactive Isotopes in Clinical and Experimental Medicine. *Doctor Joseph G. Hamilton*, University of California

DP.* The Use of Radiophosphorous as a Tracer in the Investigation of Lipid Metabolism and Phospholipid Production in Animals. *Doctor Wright H. Langham*, University of California

DP.* Preliminary Investigations With the Three Hundred Million Electron Volt Synchrotron. *Professor Ivan Getting*, Massachusetts Institute of Technology

2:00 p.m. Inspection Trips

—PAMPHLET reproductions of author's manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the technical program committee ultimately will be published in PROCEEDINGS and TRANSACTIONS; also, each is scheduled to be published in ELECTRICAL ENGINEERING in digest or other form.

***DP:** District paper; no advance copies are available; not intended for publication in *TRANSACTIONS*.

****ACO:** Advance copies only available; not intended for publication in *TRANSACTIONS*.

The Adolphus Hotel also has set aside rooms for the members with the following rates:

Single rooms	$3.50 to $7.00
Double rooms with double beds	5.50 to 9.00
Double rooms with twin beds	7.00 to 10.00
Parlor suites, consisting of two rooms	12.00 to 20.00

Special arrangements have been made with the Baker and Adolphus Hotels for the housing of students, four and five to a room, at a rate of $2 per day.

Rooms are arranged for the night of April 18 and must be vacated by Thursday evening, April 21, unless special arrangements are made for a longer stay.

If for any reason rooms cannot be obtained at one of these, other downtown hotels in Dallas which might be contacted are White-Plaza, Jefferson, and Mayfair. Suburban hotels are Melrose Court, Stoneleigh Court, Loma Alto, and Cliff Towers. Among high-grade tourist courts are Ranch 77, El Sombrero, El Rancho-Tel, and Belmont Motor Hotel.

COMMITTEES

The personnel of the District meeting committee for the South West District meeting is as follows:

Elgin B. Robertson, *chairman;* P. G. Wallace, *vice-chairman;* C. Walker Mier, *vice-chairman;* George N. Pingree *vice-president for South West District;* Gibbs A. Dyer, *secretary for the South West District*

The chairmen of the various subcommittees were listed in the March issue.

OTHER INFORMATION

A meeting of the AIEE board of directors will be held on Wednesday, April 20. There will be a luncheon on that day in honor of the directors. All members in attendance are invited.

Further information on all features may be obtained at the registration desk. A table for mail and memoranda will be maintained, as well as a special bulletin board for the posting of personal messages and notices. Schedules of inspection trips and entertainment features will be displayed there also.

Second Conference Announced for Rubber and Plastics Industries

Inspired by the success of the 1948 conference, the AIEE has scheduled a second conference on electrical engineering problems in the rubber and plastics industries for Tuesday, April 26, 1949, in Akron, Ohio. The conference will meet from 8:00 a.m. to 5:30 p.m. in the ballroom of the Hotel Portage. It will be sponsored by subcommittee on rubber and plastics industries of the AIEE general industry applications committee, together with AIEE Akron Section.

REGISTRATION AND RESERVATIONS

A uniform registration fee of $1.50 will be charged AIEE members and nonmembers alike, as a step toward making this conference self-supporting, and advance registration is requested in order to conserve time at the one day conference. Advance registration cards, including additional cards for guests, may be obtained from J. R. Dorsey, Young Men's Christian Association, Akron, Ohio, and checks should be made payable to the AIEE Akron Section. This card must be used also for reservations for the luncheon to be held in the Hotel Portage at 12:00 noon on Tuesday. The luncheon will cost $2 per plate and must be paid for by Tuesday, April 5, 1949. The registration cards should be returned to Mr. Dorsey.

Advance copies of individual conference papers will not be available. However, all of the papers will be published together in a booklet for which paid reservations may be made on the registration card. Prices for the booklet will be $1.50 to AIEE members, $3 to nonmembers. Copies of the booklet covering the 1948 conference are still available also, and may be obtained from the AIEE Order Department, 33 West 39th Street, New York 18, N. Y., at the same prices.

In regard to hotel reservations, those attending from outside Akron should communicate directly with the hotels. The Hotel Portage, 10 North Main Street, has single rooms from $3.50 up, while the Hotel Mayflower, 259 South Main Street, offers single rooms from $3.60 up.

CONFERENCE PROGRAM

The conference program will include the following papers:

1. **Motor Requirements for Rubber Mill Drives.** *R. S. Ferguson,* Goodyear Tire and Rubber Company, Akron, Ohio

2. **Motor Drives for Banbury Mixers.** *C. F. Schnuck,* Farrel-Birmingham Company, Ansonia, Conn.

3. **The Application of Electric Motor Drives to Rubber Mills.** *W. S. Watkins,* The Ohio Rubber Company, Willoughby, Ohio

4. **Motor Drives for Calenders.** *V. O. Johnson,* United States Rubber Company, New York, N. Y.

5. **Motor Requirements for Tuber Drives.** *D. J. Rose,* Firestone Tire and Rubber Company, Akron, Ohio

6. **History of Joint Industry Conference Electrical Standards for Industrial Equipment.** *L. A. Danse,* General Motors Corporation, Detroit, Mich.

7. **Joint Industry Conference Electrical Standards for Industrial Equipment (Viewed by a Rubber Machinery Manufacturer).** *T. C. Jones,* National Rubber Machinery Company, Akron, Ohio

8. **Joint Industry Conference Standards for Industrial Equipment (the User's Viewpoint).** *L. J. Willmott,* Willmott Electrical Company, Akron, Ohio

9. **Joint Industry Conference Standards for Industrial Equipment (the User's Viewpoint).** *F. L. Swanson,* United States Rubber Company, Detroit, Mich.

10. **Preventive Maintenance of Rotating Equipment in a Rubber Plant.** *T. F. Duffy,* United States Rubber Company, New York, N. Y.

Note: Papers number 2–5 represent a detailed discussion of paper number 1

COMMITTEE PERSONNEL

The subcommittee on rubber and plastics industries consists of the following members:

K. W. John, *chairman,* A. T. Bacheler, B. J. Dalton, J. A. Gienger, V. O. Johnson, G. V. Kullgren, J. F. Moore, B. D. Morgan, W. L. Ringland, C. E. Robinson, W. J. Secrest, H. L. Smith, R. F. Snyder

Historical New England

Paul Revere's statue and the old North Church in Boston, Mass., are a sample of the many interesting places to be seen within a short distance of the New Ocean House in Swampscott, Mass., where the 1949 AIEE summer general meeting will be held in June

Conference on Textile Industry to Be Held in Cambridge, Mass.

An AIEE conference on the textile industry will be held at the Massachusetts Institute of Technology in Cambridge, Mass., on Tuesday, May 3, 1949, from 10:00 a.m. to 4:30 p.m. No registration fee will be charged for this conference, which is sponsored jointly by the textile subcommittee of the AIEE committee on general industry applications and the AIEE Boston Section.

The morning session will include the following:

(*a*). High-speed movie of loom operation by Crompton and Knowles Loom Works. A half-hour film showing in slow motion the actions and functioning of the various loom parts.

(*b*). **Textile Printing Machine Drive.** *L. T. Lester,* General Electric Company, Boston, Mass. This paper will cover the details of the drive for the new high-speed cloth printing machines. It will deal with the performance of several motors on these new type printing machines and will show how tensions are maintained throughout the machine, and of wide variations of speed, diameter of print rolls, and number of colors being printed.

(*c*). **Textile Winder Drives.** *A. T. Bacheler,* Westinghouse Electric Corporation, East Pittsburgh, Pa. This paper will deal with the design, performance, and

application of various types of winding and unwinding devices covering the field of constant tension, constant speed, center core, and surface type of winding.

(*d*). **Percentage Strength Indicator.** *R. T. Pierce*, Weston Electric Instrument Corporation, Newark, N. J. A paper and demonstration which will cover the comparatively newly developed electrically operated continuous stretch indicators as applied particularly to slashers and finishing ranges in the textile industry. This device will show the actual percentage of stretch between two points in a range and will show this percentage accurately regardless of speed of operation.

The afternoon session will cover:

(*a*). **Application of Electric Control for Weft Straightening.** Prepared by the General Electric Company. This paper will be of particular interest to the textile finishing mills in that it will deal with the development and the application of electronic weft straightening equipment, how it is applied to finishing ranges, and what its application limitations are.

(*b*). **Electronic Instrumentations as Applied to the Textile Industry.** *L. E. Cuckler*, Minneapolis-Honeywell Regulator Company, Philadelphia, Pa. This paper covers details concerning the application of electronic controls as applied especially to the finishing and slashing end of the textile industry.

(*c*). **Desynchronizing Looms.** *F. D. Snyder*, Westinghouse Electric Corporation, Boston, Mass. This paper deals with the problem of eliminating weave shed vibrations by the operation of looms in pairs. Each pair of looms is operated at 180 degrees out of phase at all times so that the vibrating forces of one loom will balance the other in each pair. The paper will show how this is accomplished electrically with simple apparatus.

The following is the personnel of the textile subcommittee:

F. D. Snyder, *chairman*, S. A. Bobe, D. McConnell, A. P. Lewis, H. C. Uhl, L. T. Jester, A. W. Frankenfield, H. Haley, R. S. Stribling, R. J. Demartini, V. Sepavich, R. B. Flowers, A. F. Lukens, A. T. Bacheler

Materials Handling Conference. A one day AIEE conference on materials handling has been scheduled for Friday, May 13, in Cleveland, Ohio. Sponsored jointly with the AIEE Cleveland Section, the conference will meet in the Empire Room at the Hotel Cleveland. The topic, "Electric Equipment for Materials Handling Bridges," will be considered in several prepared papers, to be followed by round-table discussion. A more detailed program is scheduled for publication in the May issue of *ELECTRICAL ENGINEERING*.

Anderson Appointed. J. J. Anderson, Jr., of Institute headquarters, New York, N. Y., has been named to succeed H. E. Farrer as secretary of both the AIEE board of examiners and the AIEE Standards committee. Anderson was formerly assistant to Farrer, who recently retired, and was also secretary of the American Standards Association sectional committee C42. In addition, he is AIEE headquarters representative on the executive committee of the New York Section. Full biographical details of both Anderson and Farrer will be found on page 364 of this issue.

Zworykin Named Recipient of Lamme Medal for 1948

At a meeting of the Lamme Medal committee held on February 4, 1949, during the AIEE winter general meeting in New York, N. Y., Vladimir Kosma Zworykin of the Radio Corporation of America Laboratories Division in Princeton, N. J., was selected to receive the Lamme Medal for 1948. The award is being made "for his outstanding contribution to the concept and design of electronic apparatus basic to modern television."

The Lamme Medal is awarded annually under bequest of the late Benjamin G. Lamme to a member of the AIEE "who has shown meritorious achievement in the development of electric apparatus or machinery." The award will be made this year during the AIEE summer general meeting to be held in Swampscott, Mass., June 20–24.

A personal note on Zworykin appears in this issue (*page 361*).

Nucleonics Booklet. "Elements of Nucleonics for Engineers," a booklet combining the series of 11 nucleonics articles recently appearing in *ELECTRICAL ENGINEERING*, now is available from the AIEE Order Department, 33 West 39th Street, New York 18, N. Y., for 80 cents; 40 cents to AIEE members. (See page 58A.)

COMMITTEE NOTES

Editor's Note: This department is being created for the convenience of the various AIEE technical committees. It will include brief news reports of committee activities and proposed plans for such projects as special technical conferences and sessions at general meetings. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

System Engineering Committee. The AIEE system engineering committee will present papers at the summer general meeting in Swampscott, Mass., dealing with two types of system planning. One paper will describe a metropolitan system which is beginning extensive use of 66-kv lines and transformers as part of its subtransmission and distribution system. It will describe the manner in which this new system will supplement older transmission and distribution systems. Another paper will describe a typical system where generating stations are located away from the load centers and transmission lines are an essential backbone of this system.

The theme of this committee's session at the Midwest general meeting in Cincinnati, Ohio, in October will be "Economics of System Operation." Papers are planned which weigh transmission line loss cost against relative generating costs. The use of calculating board techniques in simplifying these studies will be described. It is planned also to review the problem of power inrush in energizing load areas either of the network type or radial type. This latter problem is becoming more pertinent with the greater use of automatically started equipment adapted to residential use.

Subcommittee on Infrared Applications. The subcommittee on infrared applications of the AIEE electronics committee met on January 27, 1949, in New York, N. Y. After consideration of the work of other subcommittees on infrared radiation, the following scope was adopted:

To encourage interchange of information, publication of infrared advancements, use of standard nomenclature, and adoption of standards of specifications, of testing, and of measurements in the field of infrared radiation, and in particular pursue measuring devices and their applications, observation and detection equipments, propagation and transmission studies, spectroscopy instrumentation including process control and spectral characteristics of chemical materials and optical materials relative to their use in spectroscopy instrumentation in liaison with other societies.

Plans were formulated for a technical session on infrared radiation at 1949 summer general meeting in Swampscott, Mass. The program will carry through fundamentals into the tools, and thence to application.

Work on definitions was discussed, it being pointed out that the establishment of definitions is not a function of the group, but that the group should engage in liaison and in recommendation of terms to other organizations engaged in this work. Comments on spectroscopy definitions should be made to: Harold K. Hughes, chairman, Joint Committee on Nomenclature, Sacony-Vacuum Laboratories, Technical Service Department, 412 Greenpoint Avenue, Brooklyn 22, N. Y. Comments on definition recommendations for "AIEE Definitions of Electrical Terms," should be made to: J. J. Anderson, Jr., ASA Sectional Committee C-42, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Members of this subcommittee are A. H. Canada, chairman, A. R. Dennett, W. G. Fastie, E. D. Wilson, C. S. Woodside.

Air Transportation Committee. The AIEE air transportation committee is planning a technical conference on aircraft electrical problems at the AIEE Pacific general meeting in San Francisco, Calif., August 23–26. It is anticipated that this meeting will attract considerable interest, and aircraft electrical engineers are especially invited to attend the conference and to participate in the discussion.

Joint Subcommittee on Electronic Instruments. The AIEE joint subcommittee on electronic instruments has undertaken to prepare a set of uniform methods for specifying performance of various electronic instruments. At present, specifications for cathode-ray instruments and electronic voltmeters are being prepared. The need for such uniform methods of specification is most apparent in the case of cathode-ray instruments where exact definitions have not yet been agreed upon and different interpretations of performance are possible from catalogue data. R. Feldt is chairman of the task group of cathode-ray instruments, and C. T. Burke is chairman of the task group on electronic voltmeters.

AIEE Relay Committee. The AIEE relay committee (power group) met on February 2, 1949, in New York, N. Y., to review

progress of its 11 project committees, consider a revision of Standards now being prepared for power relays, discuss joint and associated projects, and to plan for future technical papers and committee reports.

The work of the relay committee is concerned primarily with the design, application, and performance of protective relays and relaying systems. Through representation on other committees and joint working groups, activities include associated projects such as distribution construction and protection, carrier current applications, the relaying performance of instrument transformers, and circuit breaker duty on out-of-phase switching. Project committees are appointed as required for specific investigations of various phases of relay protection and they are discharged when the work is completed. Their present work includes the following.

A proposed revision of the Standards for Relays Associated with Electric Power Apparatus (ASA C37.1) is nearly completed, after incorporating comments secured on several preliminary drafts. The new Standards will modernize the previous definitions, and will amplify the bases of rating, including current, voltage, temperature, range of operating voltage, and dielectric tests. Problems of insulation levels of relay and control circuits have been found to justify a separate investigation, and the project committee now is engaged in correlating the minimum economic limitation which may be placed on the allowable voltage to be generated by solenoids and the maximum test voltage which it is economical to allow for field tests on relays. Another project committee has received comments on a second draft of a committee report which will summarize practices and recommendations on relay protection for generators.

A joint project committee (of the AIEE relay committee, the AIEE distribution subcommittee, and the Edison Electric Institute transmission and distribution committee) is investigating the correlation of distribution circuit construction and protection practices. The performance of a number of representative distribution circuits is being given detailed study in order to evaluate the influence of protective relay settings, fuse protection, conductor size, material, covering and spacing, span length and surge protection on the number of transient and especially sustained service outages. Additional performance data are being sought by this group.

Other current projects (including associated activities) include a bibliography of relay literature, relaying between industrial and utility generating systems, the relay performance of current transformers and capacitance potential devices, and a project on circuit breaker duty on out-of-phase switching.

Tentative plans have been completed for four papers to be presented at the coming summer general meeting to be held at Swampscott, Mass., in June 1949, and a number of papers are in process for either the 1949 fall meeting or later. The next meeting of the relay committee is planned for the latter part of May 1949. Suggestions from members of the Institute relative to present or future projects will be appreciated by the committee.

Standards Revisions Approved for Steam Turbine Generators

According to a recent announcement issued by the AIEE-American Society of Mechanical Engineers joint committee on steam turbine generators, final action was taken on proposed changes in AIEE Standards 601 and 602 at the AIEE board of directors meeting on February 3, 1949, and these Standards now stand approved with the recommended changes. AIEE number 601, which was a joint Standard with the ASME, covers "Preferred Standards for Large 3,600-Rpm 3-Phase 60-Cycle Condensing Steam Turbine Generators (Larger Than 10,000-Kw Rated Capacity)," while AIEE Standard 602 is "Standard Specification Data for Generators for Large 3,600-Rpm 3-Phase 60-Cycle Condensing Steam Turbine Generators (Larger Than 10,000-Kw Rated Capacity)."

The Standards originally were issued in May 1945, and in April 1948, technical paper 48-110, "Progress Report on AIEE-ASME Standard Large 3,600-Rpm Turbine Generators," by S. H. Mortensen, J. B. McClure, and C. M. Laffoon, was presented at the AIEE Great Lakes District meeting, Des Moines, Iowa, April 1–3, 1948 (also, *EE, Jun '48, pp 548–9*), which showed that, in general, the standardized machines had received the approval of the industry but that some review was in order. The committees of the ASME and AIEE analyzed the situation and proposed certain revisions which now have been adopted by both bodies. Revisions of AIEE Standards number 601 and 602 will be issued immediately. The major changes may be outlined as follows:

1. The 15,000-kw unit is changed from air-cooled to hydrogen-cooled. This decision resulted from experience which indicated that the standardized air-cooled machine had received little favor from the industry while a number of hydrogen-cooled machines had been manufactured. It seems apparent that the trend throughout the industry is towards hydrogen cooling for this size of machine.

2. The excitation on the 11,500-kw air-cooled unit is changed to provide for a main exciter only and to omit the pilot exciter and the requirement that the rheostat be suitable for regulator operation, as a direct acting regulator would be used on this machine. The main exciter is specified to be shunt-wound and sufficiently stable under manual control to permit synchronizing the generator while operating at no load rated speed and 80 per cent voltage.

3. Provision is made in the case of all machines so that where other systems of excitation are preferred either the pilot exciter or the main and pilot exciters may be omitted.

4. On all machines, the statement is made that "physical phase sequence shall be optional" so as to permit the purchaser to specify the physical arrangement of the terminals on the machine. This does not interfere with other Standards which specify how the terminals shall be designated in relation to machine rotation.

5. The steam conditions of the 15,000-kw unit are changed to 850 pounds per square inch gauge throttle pressure and 900 degrees Fahrenheit throttle temperature.

6. The clause regarding turbine capability is clarified to state that the capability applies with 2.5 inches Hg absolute exhaust pressure and with full extraction from all extraction openings.

It is believed that these revisions represent a progressive step and reflect the experiences and wishes of the industry. The committee would be glad to receive comments with regard to any features of the Standards that should be considered in future revisions.

The personnel of the AIEE group of the committee is as follows:

Frank V. Smith, *chairman;* F. S. Brown, *secretary;* R. P. Crippen; E. S. Fields; H. S. Fitch; J. H. Foote; C. M. Laffoon; J. B. McClure; S. H. Mortensen; E. I. Pollard; Stanley Stokes

New Mathematical Ideas Stressed at Applied Mathematics Conference

A conference on applied mathematics, sponsored jointly by the American Mathematical Society and the applied mathematics subcommittee of the AIEE basic sciences committee was held on January 31, 1949, during the winter meeting with Doctor Richard Courant and P. L. Alger presiding.

This conference represented a fresh endeavor to cement relations between mathematicians and engineers. One purpose of the conference was to encourage the teaching of mathematics in forms most likely to be understood and used by engineering students. Another purpose was to bring to the attention of engineers new mathematical ideas which seem useful in the solution of electrical engineering problems.

Professor L. V. Bewley, head of the department of electrical engineering at Lehigh University, presented the first paper, on the teaching of field theory to engineers. He has developed a course in the mathematical solution of field problems at Lehigh, which is so integrated with the teaching of engineering subjects that the student is supplied the mathematical tools appropriate to each problem at just the right time. The course applies the same mathematical theory to a great variety of problems in magnetic, electrical, hydraulic, mechanical, and thermal fields, so that the student comes to appreciate mathematics as an effective tool of wide application.

In the discussion of the paper, G. M. Stein, of Westinghouse Electric Corporation, referred to Professor Bewley's recent book on "Two-Dimensional Fields in Electrical Engineering," and complimented him on his presentation of so much and such diversified material of direct use to engineers in a small space.

Stein also outlined a different procedure followed in a course he has given at the University of Pittsburgh in recent years. This course starts with the analysis of fields and treats the complex functions as a solution of the field equations. This approach is of particular value in a postgraduate course, as it justifies the introduction of additional concepts like those of the Riemann plane, and of the Schwartz reflection principle, for finding the answers to new problems. On the other hand, Professor Bewley's course introduces the student first to the mathematical principles, and from these derives the fundamental field equations. In this way, the theoretical section becomes quite short, which is desirable for undergraduate work.

The second paper, by Doctor H. Poritsky, of the General Electric Company, dealt with

Summer General Meeting Committee

Members of the general committee of the 1949 AIEE summer general meeting to be held in Swampscott, Mass., June 20–24, are, front row, left to right: C. A. Corney, M. A. Princi (vice-chairman), E. W. Davis (general chairman), Mrs. Fred Haeussler, Victor Siegfried (vice-president, District 1), R. E. Muehlig (secretary-treasurer). In the back row, left to right: J. R. MacIntyre, R. G. Slauer, F. P. Taugher, A. F. Lukens, Professor R. G. Porter, J. O'R. Coleman, F. S. Bacon, H. B. McIntyre, Professor E. W. Boehne, A. L. O'Banion, R. G. Connors, J. N. Whittenton

the calculation of flux distribution, when saturation is present. He outlined four methods of solution:

1. A numerical method of approximate integration of the proper nonlinear differential equations.
2. A graphical or flux plotting method.
3. The use of the d-c board.
4. The "hodograph" method.

In the numerical method, the differential equations are replaced by approximate finite difference equations over a lattice of points, a guessed solution is substituted in the difference equations, after which "residues" are obtained, and the initial guess is improved by "relaxation" methods, until the residues become small.

The d-c board method utilizes an analogy to the conduction in a plate, whose resistance is a proper function of the current density. The resistances first are set arbitrarily, measurements are taken, and the resistances are reset repeatedly until satisfactory adjustment to the equations is reached.

In the "hodograph" method, an analogy is established between the magnetic problem and fluid flow, and the nonlinear equations of flow in the physical plane are converted into a linear system of equations in the "hodograph" plane, that is, a plane in which the velocity components are used as co-ordinates.

Doctor J. J. Smith, of the General Electric Company, presented the third paper, describing a set of tables of Green's functions, Fourier series, and impulse functions, which he has prepared, with the purpose of reducing the work required to solve partial differential equations encountered in engineering and physics.

Green's function gives the potential due to a single point charge within a given space with any assigned boundary conditions. Once this function is known, the solution for any other charge distribution generally can be found by the use of auxiliary theorems. The possibility thus opened up, of deriving many solutions from a single function—the Green's function—which can be tabulated fairly simply, should result in great economy of labor in the solution of many partial differential equations. In the complete paper, differential equations for the Green's function and their solutions are given for both a steady state and an instantaneous point source in one, two, and three dimensions. The associated Fourier series and impulse functions are tabulated also.

The final paper was presented by Doctor Richard Courant, Institute for Mathematics and Mechanics, New York University, who recently returned from an extended trip to Europe, during which he talked with many prominent mathematicians.

Doctor Courant confined almost his entire talk to the presentation of some new ideas developed by Doctor Laurent Schwartz, of the University of Nancy, France, using the Dirac function to broaden the scope of differential equation solutions.

Under the leadership of Euler, 18th century mathematicians developed a very broad theory of differential equation solutions, and applied this to many physical problems. It was found, however, that many of the functions required in solving equations were divergent, leading to mathematical inconsistencies. For this reason, during the 19th century, mathematicians developed definitions and concepts which more narrowly defined the functions that can be used properly to obtain solutions of equations. This led to the stage of rigid or classical mathematical theories of the present day. However, during the latter part of the 19th century and in the 20th century, physicists and engineers have found many problems in electric transients and in atomic physics whose mathematical solutions can be expressed in terms of functions not permissible under strict mathematical rules. Heaviside was a leader in finding solutions of such problems by methods that were partly intuitive, whose validity was at first questioned, but later has been confirmed.

Doctor Schwartz has developed mathematically strict rules for solving equations using the impulse function of Heaviside, also called the Dirac function, for the solution of differential equations, and in so doing he has considerably broadened the definitions of functions that can be employed usefully.

Doctor Courant suggested that this development will do much to unify the mathematical theories of engineers, physicists, and mathematicians.

It is hoped that a paper by Doctor Courant on this subject may appear in an early issue of *ELECTRICAL ENGINEERING*.

After the conference, the applied mathematics subcommittee agreed to invite Doctor Schwartz to speak before the AIEE at a similar conference to be held during the annual meeting next January, as Doctor Schwartz will be in the United States at that time.

Discussion of Education Occupies Two Sessions

Two well-attended sessions on education were held Thursday morning and afternoon during the AIEE winter general meeting. The first of these, "Industry's Active Part in Education," was presided over by B. R. Teare, Jr., and consisted of four conference-type papers. E. M. Strong of Cornell University spoke on "Co-operative Education at the Undergraduate Level," pointing out the various factors which go to make up a good co-operative education plan. "Industry's Co-operation in Graduate Education," was a paper by W. A. Lewis, Illinois Institute of Technology, in which he cited criteria for good graduate courses. The type of course on the graduate level that emphasizes fundamental principles and methods of analysis leading to an end-result is the type that is desirable as against a design-type course, where particular practices of a particular company are emphasized. He cited the Illinois Institute of Technology's co-operative program as an example of a good type of graduate curriculum.

K. B. McEachron, Jr., of the General Electric Company, spoke on "Internship for the Engineering Graduate." He gave a program for an internship period in industry for the graduate engineer, and pointed out that industry must be made aware of its responsibility to develop the "professional engineer" from the graduate engineer. This can be accomplished by industry if it will recognize its responsibility and develop such an internship program.

The final paper in this session was "Professional Development of the Young Engineer in Industry," by Guy Kleis and J. C. McKeon, both of the Westinghouse Electric Corporation. McKeon, who presented the paper pointed out that professional development should be considered an industrial necessity rather than an obligation to society. A program by means of which professional development can be obtained would include considerations such as a favorable atmosphere for professional development, good initial training, good follow-up training, continued education, and encouragement in professional activities.

A number of interesting points were brought out in the discussion that followed the presentation of the papers. The need for ideal conditions in running a co-operative plan was pointed out. These ideal conditions

include such considerations as that the institution running the co-operative plan should be on an all-co-operative basis and the terms should be three months in length. It was pointed out by one discussor that the co-operative plan affords men an opportunity to obtain an engineering education at low cost. On the other hand, another discussor pointed out that it was unwise to "sell" the co-operative plan on this basis, and that it was much wiser to point out to the student that the merits of the co-operative plan lie in the fact that a student is able to obtain industrial experience as well as engineering training at the same time. It seemed to be the general consensus of opinion that the co-operative plan was here to stay. A number of people in the audience cited the need for more humanitarian education, citing weaknesses of engineering graduates in English and in the ability to handle men. A number of people inquired how a small company can partake in a plan of professional development of the young engineer. It was pointed out that the AIEE education committee is doing much missionary work in this regard and has succeeded in many locations. It was mentioned also that the small company can get in on the professional development program if the top management in the company can be sold on the idea. The need for more publicity was cited also.

The afternoon education session covered a rather different phase of electrical engineering education. It was titled "Conference on Education in Power Electronics," and was presided over by J. G. Ryder. The first paper was "Scope of Power Electronics and Its Industrial Applications," and was presented by H. Winograd, Allis-Chalmers Manufacturing Company. His paper covered the industrial applications of power electronics and dealt mainly with mercury-arc rectifiers. It was suggested that a course in this field well might be taught at colleges. However, it was not recommended that electrical engineers be trained to specialize in this field. Rather, the engineer should be trained to have the proper background so that he will be familiar with the basic principles and thus be able to tackle any job which may come up in this field. C. H. Willis, Princeton University, spoke on "Power Electronics as an Educational Medium." He outlined several problems that could be used to illustrate certain basic electronic principles and that would tax the student's ability to think out a problem in terms of basic principles.

The next three papers covered power electronics courses in electrical engineering education. These were outlines of the power electronics curricula in three schools. The first of these, by M. A. Hounell and F. O. Nottingham, outlined the program at Georgia School of Technology. Ohio State University's courses were given by W. L. Davis, and Iowa State College curriculum was covered by A. W. Swago.

In the discussion that followed the presentation of the papers, it was pointed out that teaching vacuum techniques by actually constructing vacuum tubes might be a good way of illustrating or familiarizing students with problems that they might encounter when in industry. It was suggested that the same might be done for the electric machinery courses also. Slides of some specially designed laboratory equipment were shown by one discussor.

Assistance by AIEE committees to educators in power electronics was discussed by W. C. White of the General Electric Company. He suggested that yearly summaries of foreign developments, encouragement of graduate work in power electronics, suggesting good thesis topics, as well as making lists of installations for AIEE inspection trips for students, and industrial slides or motion pictures available from manufacturing companies all would serve to stimulate interest in the power electronics field and were means by which AIEE committees might be of some assistance in this regard.

The final paper on the program was a description of a "Bibliography on Electronic Power Converters," by C. R. Marcum of the Westinghouse Electric Corporation. It was pointed out that the bibliography is scheduled to be published by the AIEE in the near future.

Conference on Nucleonics Is Held During Meeting

Under the chairmanship of W. E. Barbour, Jr., and R. D. Evans, four conference-type papers were presented at the conference on nucleonics which was held Thursday afternoon during the AIEE winter general meeting.

A. P. Schreiber, Tracerlab, Inc., spoke on "Radioisotopes in Industrial Process Control." A number of interesting methods by which radioactive isotopes can be used in industrial applications were described.

"Radioactive Tracers in the Study of Friction," was presented by John Burwell, Massachusetts Institute of Technology. How the use of radioactive tracers has helped confirm modern theories of the mechanism of dry friction between smooth metal surfaces was considered.

K. Z. Morgan, Oak Ridge National Laboratory, spoke on "The Protection of Industrial Workers from Radiation."

The last paper in this session was "Quantitative Dosage Measurements by Autoradiographic Techniques," by R. A. Dudley, Massachusetts Institute of Technology. This paper described methods of determining the magnitude of local radiation dosages from radioactive isotopes nonuniformly distributed throughout an inner material using a photographic film. Though the techniques have been applied to biological problems, they can be extended readily to other types of problems as well.

Technical Session Considers New Electronic Devices

Five conference-type papers were presented at the session on new electronic devices which was presided over by W. C. White, General Electric Company.

"Synchronized Micro Time Photographic Techniques," was the subject of a paper by A. M. Zarem, Stanford Research Institute. The paper covered the circuitry and the techniques involved in a high-speed camera which uses the electro-optical shutter (the Kerr cell). W. W. Snyder of the physics laboratories of Sylvania Electric Products, Inc., presented a paper called "A Subminiature Tube Application." He described developments in subminiature decade ring counters for electronic computers. The counters each measured only 2 inches by $2^1/_2$ inches, and their compactness was made possible through the use of subminiature tubes and printed circuit techniques.

Doctor R. M. Ryder, Bell Telephone Laboratories, presented a paper called "Close-Spaced Triodes for Operation as Broadband Amplifiers at 4,000 Megacycles." A description was given of the design of a close-spaced triode for radio relay amplifier application. The close spacing of the elements grid-cathode anode held to extremely close tolerances resulted in a tube which has a high gain and is able to amplify a very wide band of frequencies.

An interesting instrument was described by J. E. Bigelow, General Electric Company, who presented a paper called "The Type-*H* Leak Detector." This leak detector is an instrument capable of detecting very small concentrations of halogen vapors in air. It is used to detect leaks in vacuum systems as well as in devices such as refrigerators where the halogen gas is contained in a closed system. A demonstration of the operation of the instrument was presented in which various halogen compounds in such articles as moth balls and driftwood were detected easily by the instrument.

"Ultrafax" was the subject of a paper by D. S. Bond of the RCA Laboratories. This was a description of the Ultrafax system which is a system for sending large quantities of information in the form of printed or written messages by means of television and photographic techniques. The lecture was supplemented by a sound motion picture which described the various steps in the process, and slides of various types of messages that can be transmitted by this system were shown.

Nerve Electricity Discussed at Conference on Energy Sources

Four conference-type papers were presented at the conference on energy sources held during the AIEE winter general meeting on Wednesday afternoon at which W. A. Lewis, Illinois Institute of Technology, presided. One of these was "Effects of Electricity on the Human Body," and was presented by W. B. Kouwenhoven, dean of the school of engineering of the Johns Hopkins University (*EE, Mar '49, pp 199-203*).

The other three papers had to do with electricity as it is produced by animals and in humans. Doctor C. W. Coates, curator and aquarist at the New York Aquarium spoke on electric fishes, describing the various types that are prevalent throughout the world and their typical characteristics. The mechanism by means of which electricity is generated in the human body in order to transit messages from central organs to the brain was covered in a paper called "Chemical Mechanisms of Nerve Electricity," by David Nachmansohn, medical doctor, of the college of physicians and surgeons, neurological department of Columbia University. He pointed out the salient facts of the theory of how nerve electricity is produced in the human body and mentioned that electric fishes, such as electric eels, were very valuable in this study. Finally, the last

paper in the session was presented by Doctor M. V. Brown, department of physics, College of the City of New York, whose paper was "Analysis of the Electric Discharge of the Electric Eel." He explained how measurements were made on the electric eel and, with the assistance of Doctor Coates, gave an actual demonstration of such measurements on a live electric eel. The fish was placed in a long narrow channel, probes were applied to the fish's body, and with the aid of a projection-type cathode-ray oscilloscope the audience was afforded a view of the voltage discharges as produced by the electric eel.

A rather lively discussion followed the presentation of Dean Kouwenhoven's paper during which such topics as shock therapy for reviving the heart, artificial resuscitation, and the possible use of electricity as an anesthetic were brought out. Much work is being done in this field at the present time.

Household Equipment Discussed at Well-Attended Friday Session

Seven conference papers and one technical paper provided a comprehensive program for a symposium on the control and protection of household equipment held on Friday afternoon of the winter general meeting under the chairmanship of M. M. Brandon. The engineering of electric appliances is one of the biggest fields in the electrical industry, and the session was intended to provide a bird's-eye-view of that field.

C. F. Scott of the General Electric Company, vice-chairman of the committee on commercial and domestic applications, opened the program with a discussion of "Appliance Design as a Field for Engineers." He pointed out that engineering electric appliances for home use is now big business; since 1926 the volume in units has gone up seven times and the volume in dollars has gone up nine times. In his discussion, Scott said that the design and building of electric appliances has been neglected, and he summarized some of the problems which will face the appliance engineer in the near future, problems such as the development of a high-frequency range for household use, preservation of food by high-velocity electrons, and vortex refrigeration.

ELECTRIC CONTROLS

N. R. Pugh of Sears Roebuck and Company presented the paper, "Types of Electric Controls Encountered in Domestic Appliances," which he had prepared in collaboration with R. Knotek of the same company. This paper provided a general review of the types of controls encountered in consumer goods testing laboratories. For the sake of the discussion, household controls were divided into three general types: control of temperature such as is necessary in electric blankets, heating pads, refrigerators; time control as in milk pasteurizers, electric ranges, electric clocks; and current or voltage control such as in fence controllers, farm lighting plants, motor overload protectors. Also considered were humidity controls such as are found in dairy barns and speed controls which are applied to electric mixers.

"The Automatic Protection of Refrigerating Machines," was considered by T. C. Johnson of the General Electric Company, Fort Wayne, Ind. His discussion was concerned primarily with the presentation of the problems peculiar to his industry in an effort to interest the audience in these problems and thus perhaps to get them solved. The main problem, of course, in the application of motors to refrigerating machines is the same as that to be found in any motor application—to get the most for the least. The refrigerating industry utilizes three types of motors; fractional-horsepower open-type motors, the hermetic type of compressor, and integral-horsepower motors for large installations (one horsepower and up).

TECHNICAL CONSIDERATIONS

In two papers of more technical interest, K. L. Cline, Durakool Inc., considered "Mercury Solenoid Relays," while C. L. Tetherow, Underwriters' Laboratories, Inc., New York, N. Y., discussed "Synthetic Load for Testing Rectifiers." In the latter paper, the author showed that to obtain reliable comparisons between input, output, and temperature characteristics of various metallic rectifier designs, it is obvious that a standard test load simulating battery characteristics is extremely desirable. An effective method seems to be a synthetic load consisting of the proper amount of capacitance in parallel with a variable resistance.

Technical paper 49-1, "Heat Pump—Its Significance as a Potential Residential Electric Load," by Constantine Bary, Philadelphia Electric Company, was presented at the session by title only.

Gas Turbine Provides Interesting Symposium Subject

A symposium on gas turbines for power generation was held on Thursday during the winter general meeting. The subject was opened by B. G. A. Skrotzki, associate editor of *Power*, McGraw-Hill Publishing Company, Inc., who presided. He explained that the symposium was arranged to bring to electrical engineers the basic fundamentals of the gas turbine and the state of the art. The war spurred the development and there is now in process a world-wide survey with about 50 units in operation so that the gas turbine is about on the threshold of commercial maturity. Beginning with the simple gas turbine cycle, Skrotzki reviewed several of the cycles, the terminology, the effect of increasing efficiency by using regenerators, and the effect of multistaging. With all of the development work that has been put into the gas turbine, he expressed the belief that it was unthinkable that the gas turbine is not going to take over its share of the load.

"A Review of High-Speed Drives for Gas Turbine Test Plants," was given by D. W. Knowles of A. V. Roe, Canada, Limited.

"A 3,000-Horsepower Gas Turbine Power Plant," in which all components are in line without a common axis of rotation was described by J. S. Haverstick of the DeLaval Steam Turbine Company. With one turbine to drive the compressor, the other turbine is left free to rotate at its own best speed. With this arrangement the power turbine speed can be reduced with a lowering of the thermal and mechanical stresses which should improve the efficiency of the cycle.

The "Elliott Gas Turbine Developments Applicable to Power Generation," were presented by Edward S. Dennison of the Elliott Company which was the first group to have a full-scale type of gas turbine running in America. The first marine plant operated on a compound cycle, which was designed to deliver 2,500 shaft horsepower to attain a thermal efficiency of approximately 30 per cent. Data were presented which showed that the actual performance was truly remarkable and a thermal efficiency of 29.2 per cent was attained. The second marine plant consisted of two rotating assemblies or "shafts." The first comprised the lower pressure compressor and the high-pressure turbine. The second consisted of the high-pressure compressor and the low-pressure turbine. The net useful output is delivered from the low-pressure turbine coupling. Performance of this type of plant was notable for high peak efficiency—33.4 per cent, and for the maintenance of a good economy down to about 30 per cent of rating.

"The Design of Gas Turbines Suitable for Peak-Load and End-of-Transmission-Line Operation," was described by W. B. Tucker of the Allis-Chalmers Manufacturing Company.

In the afternoon section of the symposium, two papers were presented. Alan Howard of the General Electric Company described "Two Gas Turbines for Power Generation and Other Applications." F. T. Hague of the Westinghouse Electric Corporation presented a paper on "Gas Turbines in Stationary Power Generation."

In discussion of the subject, Sawyer of the American Locomotive Company pointed out that there are two types of plants so that it is not necessary to take into consideration a water supply when talking about the type of plant that preheats air. Professor King of Cornell University discussed the subject from the point of view of cross-breeding to capitalize and realize reduction in the size of equipment. The cross-breeding of the Diesel and gas turbine promises improved efficiency. Another discussor, Paul Sidler, president of the Brown Boveri Corporation, commented on the scarcity of actual operating experience from gas turbines. He had hoped to gather some operating experience that they had hoped to obtain two years ago. Wilson of the Elliott Company reviewed the principles of the three basic cycles.

In conclusion, Dennison explained that the efficiencies as discussed were on the basis of higher values of the order of 33 or 34 per cent rather than the 28 or 29 per cent efficiencies as discussed by Howard. Tucker, in conclusion, did not believe that the gas turbine unit was of very great interest to the large power systems. In connection with several units in one plant, Wilson questioned the cycle as not likely to be the one previously shown. In conclusion, Howard stated that when the characteristics are known, applications will come up that cannot be foreseen.

New Tools for Research Discussed at Symposium

C. G. Suits presided over a symposium on new tools for research which was held on Friday afternoon during the AIEE winter general meeting. Seven papers covering a

broad range of topics were featured at this session.

The first of these was "Electronic Digital Computers," which was presented by H. H. Aiken, of Harvard University. He pointed out that in spite of the large size and complexity of these machines, they can do only what an ordinary desk calculator can do, only faster with less attention on the part of the operator. As the speed of calculators goes up, more complex problems are needed for the machines to solve. The coding of problems takes too long at present, and the subject of considerable research is simplification of this coding.

D. K. Coles, Westinghouse Electric Corporation, spoke on "Microwave Spectroscopy." A microwave spectroscope was described which included a microwave generator of variable frequency, apparatus for precise measurement of microwave frequency, and a means for detecting very weak absorption lines. Some results of microwave spectroscopy were presented with a discussion of their application to molecular and nuclear physics, chemical analysis, and electrical engineering.

"Use of Nuclear Spin Techniques to Measure and Control Magnetic Fields," was the subject of a paper by J. L. Lawson, General Electric Company. It was pointed out how the use of a nuclear spin and magnetic moment can be used to convert the measurement of magnetic induction to the relatively simple and accurate measurement of a frequency. Within certain limitations such as the required value of a magnetic field and its homogeneity, the use of spin techniques provides us with extreme precision in the determination or in the control of magnetic induction.

H. W. Washburn spoke on the "Mass Spectrometer as a Research Tool." The various applications of the mass spectrometer were indicated. Those of particular interest to electrical engineers include a fundamental study of the principles underlying the emmission from oxide coated cathodes, and in testing special vacuum tubes for leaks with a special form of mass spectrometer called the leak detector.

"Recent Advances in Instrumentation for X-Ray Powder Diffraction," were discussed by O. S. Duffendack, Phillips Laboratories. It was pointed out that X-ray spectrometer with the Geiger counter tube detector has been approved to allow increased angular and intensity range. The instrument is ideally suited for qualitative and quantitative analysis, and though designed primarily as a research tool it may be adapted to problems of production control and testing.

James Hillier of the RCA Laboratories presented a paper on "The Electron Microscope." An interesting point brought out in this paper was the fact that, contrary to popular belief, the electron microscope so far has been found more useful in the non-biological sciences. It was pointed out that electrical engineering of the future will be influenced appreciably but indirectly by the results which are provided by the electron microscope.

The last paper in this session was "Methods of Application of High-Speed Photography to Research," and was presented by J. H. Waddell, Bell Telephone Laboratories. A number of methods of high-speed photography, both still and motion picture types, applicable to research problems were described.

Computing Devices Conference Attracts Interested Audience

On February 4 a conference on computing devices was held with E. L. Harder of Westinghouse Electric Corporation, East Pittsburgh, Pa., presiding. Two technical papers and three conference papers, all on analog computers, were presented.

"Application of the California Institute of Technology Electric Analog Computer to Nonlinear Mechanics and Servomechanisms," by G. D. McCann, C. H. Wilts, and B. N. Locanthi, all of California Institute of Technology, Pasadena, Calif., was given by Wilts. Five groups were represented who could give good authoritative information on practical uses of the computer. Nonlinear-type problems in which a dependent variable appears as in the study of the backlash of a spring or of saturation effects were discussed. Slides showed the elements of this high-speed computer, typical functions that can be analyzed, and applications to nonlinear servo systems. The use of germanium crystal diodes was described. Questions were raised and answered regarding the maximum capacity of the machine, and the number of degrees of freedom that can be handled.

"Comparison of Long-Time and Short-Time Analog Computers," was given by Victor Paschkis of Columbia University, New York, N. Y., to explain the use of the electric analog computer for the solution of transient heat flow problems. A description was given of the apparatus at Columbia University in the heat and mass flow analyzer laboratory. The time for completion of these problems in the computer may vary from $1^1/_2$ minutes to several hours, whereby satisfactory results are obtained for either their long-time or short-time computer problems. Slides showed equipment in the laboratory and equivalent network circuits for flow problems. Questions were answered on the capacity of the computer, oscillograph recordings, and components.

"The Transient Behavior of the 2-Stage Rototrol Main Exciter Voltage Regulating System as Determined by Electrical Analogy," was presented by J. T. Carlton of Westinghouse Electric Corporation, East Pittsburgh, Pa. A description of the regulating system for the 70,000-kva 3,600-rpm turbogenerator was given. Transient field currents which increase the excitation and raise the internal voltage, thus adding greatly to the power system stability, were analyzed. Slides showed schematic and analog diagrams and the response of regulating system. Questions regarding changes in conditions which might make changes in the interpretation of the data were considered.

J. P. Corbett of Northwestern University, Evanston, Ill., presented a "Summary of Transformations Useful in Constructing Electrical Analogs of Linear Vibration Problems," which is concerned with the problem of realizing arbitrary linear systems of vibrations in terms of electric systems. Practical ways of analyzing and looking at the prototype system, the setting up of the mathematical equation, and the conversion into the analog system were explained. Charts of the setup of analogs were presented. A discussion on setting up equations and the problems that must be considered followed the presentation of the paper.

A paper entitled "A Large-Scale Analog Computer for Flight Simulation," was given by A. C. Hall of Massachusetts Institute of Technology, Cambridge, Mass. A description of the flight simulation laboratory, including the computer, at Massachusetts Institute of Technology and a résumé of the type of aircraft control and flight problems which can be handled were given. A wide range of problems on a one-to-one time scale can be solved. Slides showed the laboratory; its equipment, including the flight table and computing equipment; and system of integration used in simulator. Integrations to the 20th order can be handled. A 150 man-hour problem may be solved in approximately five seconds. A discussion followed on the methods of checking results and on the selection of time scales.

Rural Electrical Hazards Are Interesting Conference Subject

Under the chairmanship of Robin Beach, head of Robin Beach–Engineers Associated of Brooklyn, N. Y., a conference on control of electrical hazards in rural areas attracted an attendance of more than 80 to a Wednesday afternoon session of the winter general meeting. The conference featured four papers: the first three considered rural electrical hazards and grounding conditions in general, while the final paper presented was concerned with the special problems posed by the use of electric fences.

HAZARDS ON FARMS

"Electrical Hazards to Farm Stock," by W. B. Buchanan of the Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada, presented a brief summary of various points of interest in the supply of electric power, particularly in rural areas. The subject of this paper evolved from the fact that a large number of cattle had been electrocuted in their stalls and elsewhere on stock farms and such experiences were widespread. Buchanan pointed out that earth currents alone cannot be relied upon to clear the circuit by blowing fuses, but that currents and voltages of lethal values can be set up and sustained in unauthorized and remote places. He emphasized the fact however, that whatever may be done initially to provide an installation free from hazard, if such hazards are to be avoided there is need for more reliable test data in individual cases rather than relying on convenient assumptions.

"Protective Grounding of Electric Installations on Customer's Premises," was the title of a paper by A. H. Schirmer, Bell Telephone Laboratories, Inc., New York, N. Y. The paper itself is an outline of the practices which must be followed to obtain effective grounding on customers' premises—not only to prevent electric shocks but also to minimize insulation failures, and thus fire hazard. Pointing out that ineffective grounding often results because the fact that Ohm's law also applies to the electrode is forgotten, Schirmer devoted his presentation to the showing of slides which illustrated or supplemented points which had been brought out in his paper. The conclusion was drawn that the present extensive practice of interconnecting primary and secondary neutrals improves the effectiveness

of grounding, particularly in rural areas, and that it also has definite advantages from both the standpoint of lightning and faults involving primary distribution circuits.

In his paper, "Rural Neutral Potentials," J. H. Waghorne, Hydro-Electric Power Commission of Ontario, covered the results of an investigation of potentials occurring on the neutrals of the rural distribution lines of the Hydro-Electric Power Commission. Upon consideration of the potentials under normal operation, unusual loads, primary faults, and lightning surges, the conclusion was drawn that the common multigrounded neutral is the safest and most reliable ground available in the system and that all metallic enclosures should be connected to it.

Both the data presented by Waghorne and in the previously discussed paper by W. B. Buchanan are based on research on the subject which these men have been carrying on, in part for the Hydro-Electric Power Commission of Ontario, and in part for the AIEE committee on domestic and commercial applications.

ELECTRIC FENCES

The more specialized problems encountered in the installation and maintenance of "Electric Fences" was considered by Charles F. Dalziel, professor of electrical engineering at the University of California, Berkeley, in the final paper of the session. Sustained purchases of some 400,000 electric fence controllers per year by American farmers substantiate the fact that the electric fence is a practical and valuable aid to modern farming. Professor Dalziel reminded his audience that since the primary objective of the electric fence is to control farm animals by subjecting them to a powerful shock when they contact the fence wire, human beings will be affected similarly, and attention must be given to controlling the shock intensity so that it will be harmless to both man and beast. He maintained that although homemade devices often are utilized with disastrous results, electric fence controllers which are approved by institutions such as the Underwriters' Laboratories, Inc., and the Industrial Commission of Wisconsin are safe, effective, and economical. Dalziel emphasized the need, however, for the enactment of specific enforceable legislation in each state covering electric fence controllers, and for the maintenance of uniformity among the electric fence safety codes.

The session was closed with discussion from the floor during which John A. Dickinson of the National Bureau of Standards, who is chairman of the committee on electric fences, said that although the bureau does not set itself up as a body to approve electric fence controllers, it does do testing in questions of advertising claims for the Fair Trades Commission and the Post Office. In this respect, he described a committee on instruments and methods which has been set up at the National Bureau of Standards under F. B. Silsbee to obtain agreement on the subject among the bureau, manufacturers, users, underwriters, and so forth. He deplored the fact that the main drawback to the program is the lack of cooperation by users in furnishing information or participation. He appealed to those in the audience who might have contact with users of electric fences to ascertain if such users might not be willing to take part in the committee's work.

Communication Applications Subject of Meeting Session

In the session on special communication applications, held on Wednesday, February 2, five papers were presented with J. D. Booth presiding. The first paper dealt with "The Mechanism of the Supersonic Bias," by Angelo Montani, W M Instrument Corporation, while the second paper treated "Application of Experimental Test Procedures and Methods of Analysis of Results to Research Problems in Magnetic Recording," by C. S. Thompson, Bala-Cynwyd, Pa. The third paper was on "Considerations on Facsimile Transmission Speed," by H. F. Burkhard, Signal Corps. The fourth presentation dealt with "Control Chart Methods Applied to Frequency Response Curves," by A. B. Mundel of the Sonotone Corporation, while the fifth paper gave "An Over-all Inspection Program," by H. M. Wolfson of the Western Electric Company.

In discussion, a number of questions were asked which were answered by the authors. W. P. Dobson, chairman of the subcommittee on statistical applications of the Standards committee, explained that the last two papers were scheduled for presentation in a communications session rather than in a separate session on statistical applications and the interest manifested proved the arrangement worth-while.

Fine Papers Presented on General Electronics' Subjects

Although but five papers were included on the program for the session on electronics held on Friday, February 4, under the chairmanship of T. B. Kinn, the field of electronics received a much wider treatment during the 1949 winter general meeting.

According to one engineer present at the session, 160 out of the 300-odd papers delivered at the annual meeting required some knowledge of vacuum tubes or their associated circuits for their understanding. However, the vast majority of the 160 papers were assigned to those fields of interest or sessions to which the particular electronic device applied. The five papers heard by those who attended the "electronics" session fell into two categories. They could not be classified under the headings of any of the other sessions, or they were just "electronics for electronics' sake," with no specific application.

The first paper, offered by T. Slonczewski of the Bell Telephone Laboratories, New York, N. Y., dealt with "Transconductance as a Criterion of Electron Tube Performance." The author described a method of quantitatively evaluating the performance of electron tubes, specifically pentodes. Under certain conditions, however, the method can be applied to triodes. The material consisted chiefly of a list of formulas which can be used in computations of the transmission and quality of transmission of vacuum tubes, and Slonczewski demonstrated at the blackboard how his formulas would be used. He also described how visual examination of the tube-characteristic curves would tell the engineer the type of modulation present.

J. J. Larew of the General Electric Company, Schenectady, N. Y., described "A New Standard Frequency Source with Power Output Up to 10 Kw." The equipment described consisted of a standard motor-generator set which was electronically controlled to maintain the output voltage in synchronism with a frequency supplied by a tuning fork. Briefly, a comparator receives two signals, one, from a conventional tuning-fork oscillator through a phase-shift bridge, and the other, from the a-c alternator of the motor-generator combination. The comparator compares the phase of the tuning fork signal to the phase of the alternator output voltage, and regulates the field of the d-c driving motor to maintain synchronism. This equipment is stable under all types of load conditions and has a full-load efficiency of the order of 65 per cent.

Comments on details of the circuit were made by S. E. Moore of the Philadelphia Electric Company, Philadelphia, Pa., and H. F. Storm of the General Electric Company, Schenectady, N. Y.

"High-Voltage Rectifier Tubes with Thoriated Tungsten Filaments," which find their application in the fields of medical X-ray work or crystallography, were depicted by Z. J. Atlee of the Dunlee Corporation, Chicago, Ill. Atlee outlined the design problems which he had to solve in order to produce a thoriated-tungsten filament which would function at voltages in excess of 100 kv. He described how he achieved the necessary extremely high vacuum, the method of filament processing, and the optimum configuration of elements within the tube. Indications are that thoriated tungsten will replace tungsten as a filament material in many other high-vacuum tubes, such as power tubes.

According to W. C. Johnson of Princeton University, Princeton, N. J., who delivered "Universal Curves for D-C Controllable Reactors (49–4)," he and his two coauthors tried three different approaches to this difficult subject. Then, they threw out two on the theory that if the parents did not like the child, then others would think it a brat, indeed. B. C. Merrell of Proctor and Gamble, Cincinnati, Ohio, and R. E. Alley, Jr., of the University of Richmond, Richmond, Va., were his collaborators. The point also was brought up that although the d-c reactor bears no physical resemblance to a vacuum tube, it was included in the session on electronics because it acts like one.

It is the opinion of the authors that their paper presents the first reasonably quantitative analysis of the behavior of d-c controllable reactors to date. Their paper treats the steady-state characteristics only. The results they obtain are applicable to the calculation of the characteristic curves of a reactor from either its d-c or a-c saturation curve. The universal curves can be used in either a quantitative manner or they can be used qualitatively, to enable one, for example, to determine the effect of using a magnetic material with different characteristics. The authors' analysis also permits the calculation of d-c flux linkage, a knowledge of which is essential to the computation of transient characteristics.

E. C. Wentz of the Westinghouse Electric Corporation, Sharon, Pa., stated that this was the first paper he had seen that got down to the basis of core design and selection of materials. L. A. Finzi of the Carnegie Institute of Technology, Pittsburgh, Pa., told of similar work that he has been doing

in Pittsburgh. He related that he had been using different mathematical functions in analyzing the curves, but both his and the authors' methods gave roughly the same results.

The field of X-ray tubes came in for further consideration when S. Gilman of the American Machine and Foundry Company, New York, N. Y., offered the paper, "Compact Radiographic Tubehead Using Forced Air Cooling." Gilman's coauthor was J. Lempert of the Westinghouse Electric Corporation, Bloomfield, N. J. The author described an improved tubehead design which allows the anode to be cooled directly, and permits the circulation of oil through the tubehead. The oil is circulated through the head by means of a pump. In addition to more uniform temperatures, better efficiency of heat transfer from the tubehead to the surrounding air is accomplished by bringing up the temperature of those parts which previously dissipated negligible heat when natural convection alone occurred.

Conference Considers Testing of Dielectrics in the Field

Eight interesting papers were presented at a morning and an afternoon session on the subject of testing dielectrics in the field, on Tuesday, February 1, 1949, and covered high- and low-voltage d-c tests; potential distribution tests; and high-, low-, and intermediate-voltage a-c tests. Frank C. Doble, president of the Doble Engineering Company, Belmont, Mass., and chairman of the subcommittee on electrical tests on dielectrics in the field, presided at both sessions.

"Practices and Trends in Low-Voltage D-C Tests on Dielectrics in the Field," was the title of a paper presented by E. B. Curdts of the James G. Biddle Company, Philadelphia, Pa. This paper was separated into four distinct parts—purpose of tests, instrumentation, testing techniques, and applications to various kinds of apparatus, and an attempt was made to give the economic aspects of the problem of preventive maintenance the prominence that it deserves. Present practice indicates that from this point of view the tests can be justified in many instances.

A paper on the "Insulating Resistance Tests of Low-Voltage D-C Cables" by Reginald Middleton, Metropolitan Transit Authority, Boston, Mass., was presented by L. A. Gray of the Simplex Wire and Cable Company, Cambridge, Mass., who also presented a paper entitled "High-Voltage D-C Tests on Insulated Cables."

"Potential Distribution Tests," was the title of a paper presented by Frank C. Doble describing the evolution of equipment for live-line testing of insulators, both pin- and suspension-type, utilizing the principle of voltage-distribution measurement. The extension of this technique to bushing testing by measurement of the voltage distribution over the procelain rainshed also was described.

I. G. Easton of the General Radio Company, New York, N. Y., in his paper on "Low Voltage A-C Testing," pointed out that a correlation exists between the dissipation factor of an insulating material and its moisture content. Changes of this quantity are used successfully to check on the condition of bushings and similar insulating structures. Both dielectric constant and dissipation factor of insulating materials change in a complicated manner with temperature, humidity, and frequency. In practically every important case the variation is such that at a given frequency near the power range, it will be found that dissipation factor increases with increase in moisture or temperature. As the voltage applied to the material is varied, however, it is found that no significant changes occur until the insulation is stressed to the point where corona occurs. The author concluded that essentially the same information can be obtained by a low-voltage measurement as by a measurement at fairly high voltage.

Discussion brought out that such a low-voltage test might overlook certain types of faults. Also that there are possible difficulties in correlating the results of such tests with the present standards based upon millions of tests at power frequency.

"Common Circuit Arrangements for A-C Tests on Dielectrics in the Field," was the title of a paper by E. D. Doyle and presented by W. G. Amey, both of Leeds and Northrup Company, Philadelphia, Pa. The paper described problems on a-c testing which usually have no exact counterpart in the laboratory. The solution of these problems require one or more of the following provisions: suitable source of test voltage; suitable circuit arrangements for testing a specimen which has one terminal grounded; arrangements for guarding against disturbances from other nearby high-voltage high-power circuits; and guarding against stray leakage from the test source itself.

The paper on "Intermediate-Voltage A-C Tests in the Field," by I. W. Gross of the American Gas and Electric Service Corporation, New York N. Y., reviewed the experience of his company during the past 20 years in using power factor testing of high voltage in the field. The epidemic of bushing failures experienced at the start now has been reduced to a practical minimum. The tests set and method first proposed by the Doble Engineering Company has been highly developed, and its use is now routine on the entire company's system for testing other major high-voltage equipment, besides bushings and circuit breakers, such as transformers, cables, potheads, insulators, lightning arresters, and fibrous insulation including wood. Be detecting the faulty conditions in equipment before failures occurred, and by prompt replacement or servicing, expensive repairs have been reduced, electrical service continuity and reliability have been improved, and over-all economy of equipment maintenance has been attained.

A. L. Brownlee of the Commonwealth Edison Company, Chicago, Ill., spoke on "Testing of Insulation at High-Voltage Alternating Current," in which he spoke about the use of high-voltage power factor in determining the condition of the insulation and its stability under a-c stress. The numerical value of power factor, its constancy at a constant voltage, or its change with changing voltage give indications of condition and stability of an insulation. The ideal power factor versus voltage curve is a straight horizontal line at least to operating voltage. Any deviation from this form is undesirable. The deviations that occur may be either increases or decreases in power factor with increasing voltage, depending on the mechanism that is involved, namely, corona, moisture, carbonization, or other.

System Engineering Considered at Session on Thursday

The mechanical and electrical engineers who gathered on the 18th floor of the Statler Hotel, at 9:30 the morning of February 3, attempted to bridge the gulf between their respective specialties in their consideration of "System Engineering." Educationally speaking, however, the electrical engineers were on the receiving end. Four of the five papers presented dealt with problems that are mainly mechanical.

The electrical side of the fence was represented by J. B. Ward's paper, "Equivalent Circuits for Power-Flow Studies," Ward being a member of the faculty of Purdue University, Lafayette, Ind. Three means of reducing the size of networks for power-flow studies were demonstrated. Two of these reduction procedures are now in use, but the third is an entirely new kind of analysis. It is based on the treatment of loads and generators as constant-current quantities.

"The only reason we didn't use this method before was that we didn't know about it," E. E. George of Ebasco Services, New York, N. Y., commented enthusiastically. C. E. Parks of the Public Service Company of Indiana, Indianapolis, thought that the new procedure promulgated by the author is by far the most accurate available.

G. D. Floyd of the Hydro-Electric Power Commission of Ontario wanted to know if conditions could be varied within this particular equivalent circuit.

In closing the discussion, Ward replied that once an equivalent circuit is derived for a particular system, it will represent many operating conditions.

Fluctuating loads and their relationship to steam plants, boilers, and turbines was the general topic of the other papers heard by the session.

One of the suggestions that G. H. McDaniel, of the American Gas and Electric Service Corporation, New York, N. Y., made in his paper, "An Operating View of the Problem of Fluctuating Loads on Steam Plants," was that the barrier between the boiler room and turbine room should be broken down. Automatic control, he maintained, should be extended from turbine to boiler combustion room, permitting under- or over-firing for load regulation purposes.

Both authors had a hand in the presentation of the paper, "Design of Boilers and Controls for Fluctuating Load." P. R. Loughin of the Babcock and Wilcox Company, New York, N. Y., talked on boiler design, first, and then his colleague, P. S. Dickey of the Bailey Meter Company completed the thesis, speaking on the control aspect of the problem. The authors emphasized that the interrelationship of controls and boiler design is of the utmost importance.

The "Effect of Fluctuating Load on Steam Turbines," was the paper offerred by R. L. Reynolds of the Westinghouse Electric Corporation, Philadelphia, Pa. He brought out one point that was mentioned also by the other authors. Older turbogenerator units,

he stated, are not especially adapted for the purpose of handling fluctuating loads, although that is the job that generally is assigned to them. Newer units, because of their superior design and construction, can handle fluctuations just as well, if not better.

E. E. Parker and C. W. Ellston, of the General Electric Company, Schenectady, N. Y., asked a pertinent question in the title of their conference paper, "Are Modern High-Pressure High-Temperature Turbines Suitable for Use with System Speed and Load Control?" Considerations of the effects of varying loads on turbine performance and maintenance, load change rates, and governing systems led the authors to a conclusion which was somewhat similar to those of the other papers, namely, that modern steam turbines will be found as satisfactory as the units now in service when applied to system speed or load control.

In the discussion which was held up until all the four related papers had been given, C. N. Metcalf of the Consolidated Edison Company, Inc., New York, N. Y., stated that, taking all the papers together, those present at the session had heard a well-integrated presentation of the topic of fluctuating loads.

R. Brandt, who presided at the session, and who is affiliated with the New England Power Company, Boston, Mass., thought that the authors had not settled one controversial point, namely, the desirability of carrying load control right into the boiler room. He stated that he had sent questionnaires to a large number of companies, and only three out of 50 of these indicated that they do carry load control into the boiler room. At a future date, the answers to these questionnaires will be compiled and published as a conference paper entitled, "Status of Automatic Load and Frequency Control Equipment." Copies will be sent to all who returned the questionnaires.

Fractional Horsepower Papers Arouse Great Interest at Session

The session on fractional horsepower machinery, held Thursday, February 3, was marked by a large volume of discussion from the floor. M. L. Schmidt, General Electric Company, Fort Wayne, Ind., presided over the session and introduced the speakers.

Technical paper 49-69, "Die Cast Rotors for Induction Motors," was presented by L. C. Packer, Westinghouse Electric Corporation, Springfield, Mass., and covered the machining of rotor parts and the co-ordinated efforts of manufacturing and design engineers. In the discussion that followed, Lanier Greer, design engineer for the Reliance Electric and Engineering Company, Cleveland, Ohio, showed concern with contamination of machined parts from the use of unpure scrap metal. Comments by W. R. Bennett of the Lima, Ohio, plant of the Westinghouse Corporation were read.

The second paper, 49-70, "Armature Iron Losses in Series Motors," was read by J. H. Karr, Robbins and Myers, Inc., Springfield, Ohio, one of the two authors. This paper, accompanied by explanatory slides, showed the origin and distribution of iron losses in universal motors and was offered as a preliminary to a method for future universal motor design. L. C. Packer, author of the first paper read, offered the audience a formula for checking out losses, and cited another formula, developed by C. E. Wilson, present head of General Motors, for checking back on test values. Discussion was closed by S. S. L. Chang, coauthor of the paper.

Most controversial of the session's papers was presented by L. C. Schaefer, Westinghouse Corporation, Lima, Ohio. On "Fundamental Theory of Inherent-Overheating Protection Under Running Overload Conditions," it covered the analytical approach to the problem, and presented formulas derived by the authors whose conditions, if met, would afford complete protection.

"The Field Fluxes of the Shaded-Pole Motor," 49-72, was presented by Professor E. E. Kimberly of Ohio State University, Columbus, Ohio. Professor Kimberly covered his work in the field of fractional horsepower motors during the past 20 years and showed his more recent progress through graphs he has plotted from results of his experiments. There was no discussion.

The last presentation was to have been a conference paper prepared by S. S. Wolff, Century Electric Company, St. Louis, Mo., but at the request of the committee, Wolff is revising his paper to make it acceptable for publication. He did, however, cover the essential material in his paper, including a description of "An Automatic Test Board for Fractional Horsepower Motors," that has been developed by his company to speed motor production, and the standards and conditions under which this board works.

Friday Session Covers Subject of Servomechanisms

On February 4, a session was held on servomechanisms at which G. S. Brown of Massachusetts Institute of Technology, Cambridge, Mass., presided. Three technical and one conference paper were presented.

"Damper Stabilized Instrument Servomechanisms," given by A. C. Hall of Massachusetts Institute of Technology, Cambridge, Mass., covered new techniques used to stabilize servomechanisms so that they possess a margin of stability; that transients are well damped, and that the value of system parameters can have a reasonable tolerance. Three stabilizing methods in common use; cascade compensation, feedback compensation, and load compensation were discussed. The design of viscous damper stabilized servomechanisms and of spring, coupled damper stabilized servomechanisms, which are of the load compensation method, were explained and compared. Discussions followed the paper on the use of spring damped stabilizers on synchronous motors, and on comparison of this damper stabilization method with other methods, especially with feedback systems.

"Graphic Determination of Transfer Function Loci for Servomechanisms Components and Systems," by E. C. Easton of Rutgers University, New Brunswick, N. J., and C. H. Thomas of Harvard University, Cambridge, Mass., was presented by Thomas. This paper covers the method of determining, while designing a linearly operating control system, for the uncompensated system the variation with frequency of amplitude and phase of the transfer function. The method of analysis and experimental applications were discussed. Slides were shown of the system tested, of a schematic setup for measuring the transfer function locus, and of a transfer function locus showing a comparison of measured and calculated points. A discussion of the practical use of this method to determine the transfer function locus in aircraft testing and of its application to hydraulic servomechanisms followed.

R. J. W. Koopman of Washington University, St. Louis, Mo., presented a paper on "Operating Characteristics of 2-Phase Servo Motors." A study of these motors had been undertaken because of their unusual characteristics. Performance of the servo motor having typical equivalent-circuit parameters is analyzed by means of symmetrical-component theory. Numerous interrelations between motor design and control system design were pointed out, and slides giving characteristic curves for the motor were shown.

"A New Field, Systems Engineering," was presented by H. T. Marcy of the M. W. Kellogg Company, Jersey City, N. J. A description of the problems and the outlook in this new field were discussed. It is entirely new because it is concerned with elements, the combination of which is not known. A procedure for approach to the many problems was given. This 9-point program included such factors as determining the systems dependent and independent variables, the over-all balances which must be maintained, necessary controls, and, finally, the starting of design and fabrication. An organization of results is necessary. A discussion of the need for a new terminology and the consideration of systems followed.

PERSONAL NOTES.....

Vladimir Kosma Zworykin (M '22, F '45), vice-president and technical consultant, Radio Corporation of America Laboratories Division, Princeton, N. J., will receive the Lamme Medal for 1948 at the AIEE summer meeting. The award is being presented "for his outstanding contribution to the concept and design of electronic apparatus basic to modern television." Born in Mourom, Russia, July 30, 1889, Zworykin was educated at the Petrograd Institute of Technology. Following a period of graduate work in Petrograd, during which time he performed his first experiments with television, he went to Paris in 1912 to enroll at the College of France. When the first World War broke out, he returned to Russia to serve as an officer in the Radio Corps of the Russian army. At the close of hostilities, he came to the United States, joining the research staff of the Westinghouse Electric Corporation, East Pittsburgh, Pa., in 1920. While with Westinghouse, he carried out investigations in the field of photoelectric emission. Also, he

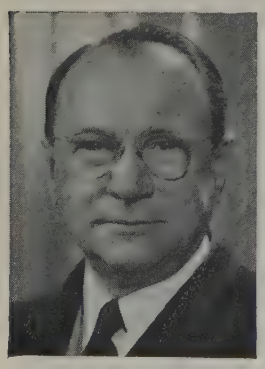
resumed his research in television, developing the basic principles of the iconoscope, then a revolutionary new type of television pickup tube, and directing a group of engineers which applied the tube to practical picture transmission. In 1929, Doctor Zworykin became director of the electronic research laboratory of the Radio Corporation of America Manufacturing Company. Besides continuing his television research, he worked on many other phases of electronics, especially electron optics. His studies led to the development or perfection of such devices as secondary emission multipliers, image tubes, as well as the electron microscope. With RCA up to the present time, he was named associate research director in 1942, director of electronic research in 1946, and was appointed to his present position in 1947. Zworykin has received two degrees since coming to the United States, doctor of philosophy, in 1926, from the University of Pittsburgh, and doctor of science, in 1938, from the Polytechnic Institute of Brooklyn. Some of the awards that he has received for his scientific achievements are: the Morris Liebman Memorial prize, 1934, for his contribution to the development of television; the Overseas Award from the British Institution of Electrical Engineers, 1939; the Modern Pioneer Award from the American Manufacturers Association, 1940; the Rumford Medal from the American Academy of Arts and Sciences, 1941; and the Howard N. Potts Medal from the Franklin Institute for his work in commercial television, 1947. Zworykin belongs to the Institute of Radio Engineers, the American Physical Society, the American Association for the Advancement of Science, the Electron Microscope Society of America, and Sigma Xi, the last being a science research honor society. He is the coauthor of several books on photocells, television, electron optics, and photoelectricity.

J. F. Fairman Nominated for Institute President

James F. Fairman (A '20, M '27, F '35), vice-president, Consolidated Edison Company of New York, Inc., New York, N. Y., has been nominated for the presidency of the AIEE for the 1949–50 term. Born in Big Rapids, Mich., on April 8, 1896, he received his bachelor of science degree in electrical engineering in 1918, and his master of science degree in 1921, both from the University of Michigan. After taking the graduate student course of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., he returned to the University of Michigan, and served as instructor in electrical engineering from 1919 to 1922, when he was appointed assistant professor. In 1925, he joined the Brooklyn Edison Company as an assistant outside plant engineer. In 1926, he became a full-fledged outside plant engineer, and later in the same year assistant electrical engineer. He was appointed electrical engineer of that company in 1932. In 1937, he became electrical engineer of the Consolidated Edison Company of New York, Inc., and in 1941 was appointed assistant vice-president for design, inventory, purchasing, and stores. On December 26, 1945, he was elected vice-president of the company and is in charge of electric and gas production and operation. Busy in AIEE activities, Fairman has served on the following technical committees: education, 1941–42; electric machinery, 1936–37; and general power applications, 1934–36. Further, he has been chairman of the New York Section, 1940–41, vice-president of the Institute, 1944–46, and director since 1946. He has served on many general committees, including: board of examiners, 1941–44; technical program, 1941–42 and 1945–47; executive, 1944–47; finance, 1944–46; safety codes, 1931–34; and Institute publicity, 1946–47. He has been a member of the committee on planning and co-ordination since 1945, and was chairman, 1945–47, when the study of organization was one of its major projects. In addition to this, he is a member of the special committee on Institute dues, and of the Edison Medal committee for the term 1947–49. Fairman served as AIEE representative on the Engineers' Council for Professional Development, 1938–44, and has been a representative on the board of trustees, United Engineering Trustees, Inc., since 1947, being at present a vice-president. Fairman has been equally active as a member of the National Society of Professional Engineers, beginning in the Kings County Chapter where he was president for three terms, followed by two terms as president of the New York State Society, 1942–44. He served as director of the national society, and two terms as vice-president for the northeastern area, 1946–47. The author of a number of papers on professional subjects which have appeared in the *American Engineer* and *ELECTRICAL ENGINEERING*, he is a member of Sigma Xi, Tau Beta Pi, Engineers' Club of New York, and the Brooklyn Engineers' Club, and is a trustee of the Flatbush Savings Bank.

Vice-Presidential Nominees Are Veinott, Seeley, DuVall, Hopkins, Frampton

Cyril George Veinott (A '28, M '34, F '48), manager, induction motor section, industrial motor engineering department, Westinghouse Electric Corporation, Lima, Ohio, has been nominated for the office of vice-president of the Middle Eastern District (number 2). A native of Somerville, Mass., he was born February 15, 1905. Graduating from the University of Vermont in 1926, with a bachelor of science degree (he received an electrical engineering degree from the same university in 1933), he joined the Westinghouse Electric Corporation, where he took the company's graduate student course. A year later, he became assistant to the chief engineer, working on problems related to commutation, ventilation, and facsimile picture transmission. From 1929–40, he was design engineer in the small-motor engineering department. His achievements included the design and development of many types of a-c fractional-horsepower motors, the application of thermal overload protection of the built-in type to Westinghouse's line of motors, and the development of new methods of performance calculations. Promoted to special development engineer in 1940 in the company's Springfield, Mass., branch, he assisted in the design of rectified a-c systems and a lightweight 40-kva 400-cycle alternator for aircraft. In addition, he made special studies of loom motors and of the problems of cooling and ventilation at altitudes up to 60,000 feet. As manager of the induction-motor section, from 1945 to present date, he has been responsible for 60 per cent of the output of Westinghouse's Lima plant. Holder of a 1936 Eta Kappa Nu citation, which is presented to outstanding young electrical engineers, he holds an Order of Merit awarded by his company and about a dozen patents in the small motor field. An author, he has written one book on fractional-horsepower motors, a section in the "Standard Handbook for Electrical Engineers," and a score of articles, many of which have appeared in the AIEE *TRANSACTIONS*. In the Springfield, Mass., Section, during the years 1930–38, he was chairman of the meetings and papers committee, secretary-treasurer, vice-chairman, and chairman. A director of the Dayton Section, 1945–47, he was a member of the rotating machinery committee, 1934–38 (then, the electric machinery committee), 1942–46, and is a member the present year. He is a member of Phi Beta Kappa.

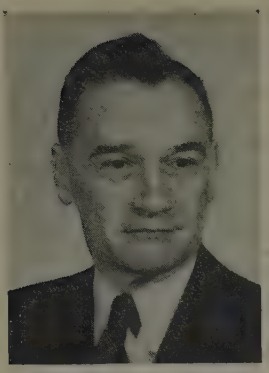


V. K. Zworykin

J. F. Fairman

C. G. Veinott

Walter James Seeley (A '19, M '28, F '45), chairman, department of electrical engineering, Duke University, Durham, N. C., is the vice-presidential nominee for the Southern District (number 4). Born November 30, 1894, in Hazleton, Pa., Seeley attended the Brooklyn Polytechnic Institute receiving his electrical engineering degree in 1917. During the next two years, he was an ensign in the United States Navy, where he helped to develop and install submarine detectors. After his war service, he joined the staff of the University of Pennsylvania as an instructor in electrical engineering. While working at the university, he was also part-time assistant to the consulting engineer on street lighting for the city of Trenton, N. J., and did some



W. J. Seeley

W. C. DuVall

R. A. Hopkins

A. H. Frampton

design and testing work for manufacturers of radio equipment. He received his master's degree from the university in 1924. In 1925, he became assistant professor of engineering at Duke University, and in the same year, head of the department. He was made a full professor in 1929. His summers during the years, 1928–40, were occupied by special assignments from the Duke Power Company, Charlotte, N. C., related to the problems of transmission and maintenance. He became associated with the Naval Ordnance Laboratory in White Oak, Md., in 1941 and worked intermittently at Duke and the laboratory. Three years later, he was granted a leave of absence from the university to become personnel director of the White Oak activity, but shortly thereafter, he was called back to Duke to administer its Navy V-12 program. However, Seeley continued as a part-time consultant for the laboratory until 1946. A participant in AIEE activities, he has belonged to the following committees: Student Branches, (1932–3); research (1937–40); and basic sciences (1945–6, 1948–9). Other organizations with which he is affiliated are: the American Association for the Advancement of Science; the American Society for Engineering Education; and the Institute of Radio Engineers. A past president of the Naval Ordnance Laboratory Technical Reserve, he is the author of texts on impedance computations and operational calculus.

Willet Clinton DuVall (A '17, M '20, F '38), head of the electrical engineering department, University of Colorado, Boulder, has been nominated to the office of AIEE vice-president, representing the North Central District (number 6). A holder of two degrees from the University of Colorado, bachelor of science (1912) and electrical engineering (1922), DuVall was born January 21, 1888, in Jefferson, N. C. After working for the Fairbanks Morse Electrical and Manufacturing Company, Indianapolis, Ind., for two years (1913–15), he joined the staff of the University of Pennsylvania, Philadelphia, Pa., as an instructor. Made an assistant professor in 1918, he moved to Boulder in 1919 to become associate professor at the University of Colorado. He became a full professor in 1922. DuVall occupied some of his summers working on assignments for industrial companies, and in 1928, he spent six months making a stability study of the Big Creek–Los Angeles 200-kv lines for the Southern California Edison Company. A member of three honorary engineering societies, Eta Kappa Nu, Sigma Tau, and Tau Beta Pi, DuVall is past chairman of the Denver Section and was a member of the Student Branches committee, 1938–41. He also belongs to the American Society for Engineering Education.

Ralph A. Hopkins (A '19, M '35), supervisor, central station and transportation department, Westinghouse Electric Corporation, Los Angeles, Calif., is the nominee to the office of AIEE vice-president for the Pacific District (number 8). A graduate of Stanford University, class of 1907, Hopkins was born September 11, 1883, in Providence, R. I. Following graduation, he joined the Westinghouse Electric Corporation, East Pittsburgh, Pa., as an apprentice. Two years later, he was transferred to the sales department in Los Angeles where his duties consisted of both engineering and selling. In 1921, he became associated with the company's central station department, and after three years he was appointed manager of that division, having been in charge of its activities up to the present time. Secretary of the AIEE Los Angeles Section, 1923–24, and its chairman, 1925–26, he served on the membership committee 1943–45. Busy in local activities, Hopkins' affiliations include: the Los Angeles Engineering Council of Founder Societies, the Los Angeles Electric Club, and the Pacific Coast Electrical Association.

Arthur Herbert Frampton (A '21, M '28, F '45), recently appointed general manager, English Electric Company of Canada, Ltd., St. Catherines, Ontario, Canada, is the Canadian-District (number 1) nominee for the office of vice-president. Born May 23, 1899, in Gillingham, Kent, England, Frampton joined the Hydro-Electric Power Commission of Ontario in 1917 as an assistant in the high-tension and general testing section. Four years later, he matriculated at the University of Toronto, and graduated with honors in 1925. He then was made assistant engineer in the station section of the electrical engineering department of the Power Commission, in which capacity he was largely responsible for technical studies and load calculations during the first planning of the commission's 230-mile 230-kv transmission system. Appointed assistant to chief electrical engineer in 1930, he was made assistant head of the electrical engineering department eight years later. He was directly responsible for all phases of the development of the entire Hydro-Electric Power Commission's system, the latter totalling over 1,600,000 kw of power. An active Institute member, he has served on the following committees: power generation, 1942–46, as chairman, 1947–49; Sections, 1946–47; Standards, 1947–49; technical program, 1947–49; and power co-ordinating, 1947–49. Functioning in an executive capacity in the AIEE Toronto Section since 1939, he also has presented several papers before Institute meetings, one of these being a prize student paper in 1925, and another, a District 10 prize paper in 1941, Frampton being a co-author of the latter. He is a registered member of the Association of Professional Engineers of the Province of Ontario.

Scholz, Davis, and Hinson Nominated as Directors

Herbert J. Scholz (A '21, M '39, F '45), vice-president of the Commonwealth and Southern Corporation service organization, Birmingham, Ala., has been nominated to serve on the AIEE board of directors. Born May 10, 1892, in Campbell, Calif., he is a graduate of Leland Stanford University, class of 1915. Starting his career as a meterman with the Pacific Gas and Electric Company, San Jose, Calif., he later went to Schenectady, N. Y., to accept a position in the testing department of the General Electric Company. After serving in the Coast Artillery, 1917–19, he returned to Schenectady, where he assisted in the design of power transformers. In 1921, he joined the Alabama Power Company as assistant operating engineer, later becoming associated with its affiliate, the Dixie Construction Company. Here, he worked on a hydroelectric development on Alabama's Coosa River. After four years, he became electrical section head of Allied Engineers, Inc., the Dixie Construction Company's successor, supervising the design of substations, transmission lines, and generating plants, constructed for the Commonwealth and Southern Corporation. During the next six years, equipment possessing 450,000 kw of generating capacity was constructed. In 1931, Scholz was made supervisory engineer for the Commonwealth and Southern Corporation, where he directed studies, covering a co-ordinated plan for the development of interconnections in the Birmingham area, and co-ordinated design practices. Eight years later, he supervised the organization of a staff to design new plants and substations. To date, this group has handled the design of 1,000,000 kw of either new plant capacity or additions to plants. For three months in 1945, he was a

member of the Utilities Team in Germany, whose duty it was to investigate and report on the practices of German utilities for the Technical Industrial Intelligence Committee of the United States Government. In 1947, he was appointed to his present position as vice-president of the Commonwealth and Southern Corporation. Active in the AIEE, he served on the protective devices committee, 1931–35, the power transmission and distribution committee, 1932–39, the transmission and distribution committee, 1940–42 and 1947–48, and the membership committees, 1946–48. At present, he is chairman of the Alabama Section of the Institute. He holds extra-Institute memberships in the International Conference on Electric High-Voltage Systems (CIGRE), the Electric Power Capacity and Requirements Task Group of the National Securities Resources Board, the Southeastern Regional Interconnected Committee, and the Birmingham Engineers Club. In addition, he is chairman of both the joint Edison Electric Institute-Bell System subcommittee on rural joint use and the power co-ordination committee of the Southeastern Electric Exchange.

Edward Wilson Davis (A '37, M '43), chief engineer, Simplex Wire and Cable Company, Cambridge, Mass., has been nominated to serve on the AIEE board of directors. A native of Shelbyville, Ky., born June 14, 1908, he attended the University of Louisville. Following his graduation in 1928, he became a student engineer with the Louisville Gas and Electric Company. A test engineer, one year later, with the General Electric Company in Schenectady, N. Y., he was transferred to New York City in 1931, where he worked on such equipment as rotary converters, mercury-arc rectifiers, and automatic switching apparatus. With the New York Board of Transportation, 1932–35, he was, for a time, in charge of a group which was responsible for the operation of several substations, his later responsibilities being the preparation of material specifications, special tests, and maintenance instructions. In 1937, he became a senior engineer in charge of electrical engineering work for Standard Oil Development Company, Elizabeth, N. J. Drawing up specifications, requisitioning of supplies, preparing engineering standards, and doing field survey work, were some of his duties. The many AIEE committees on which Davis has served are: power transmission and distribution, 1939–43; electric welding, 1946–48; land transportation, 1946–48; insulated conductors, 1947–49; and mining and metal industry, 1947–49. During the year 1946–48, he served as vice-president representing the Northeastern District (number 1).

Noel B. Hinson (A '19, M '26, F '35), vice-president and executive engineer of the Southern California Edison Company, Los Angeles, has been named to the AIEE board of directors. A native of Evansville, Ind., he was born December 25, 1885. In 1906, he joined the Edison Electric Institute (the Southern California Edison Company's predecessor) as a testman. Transferred to the general office distribution department in 1912, he was promoted to distribution engineer one year later and put in charge of the general system layout. Appointed assistant superintendent of distribution in 1920, he was made system planning engineer and chairman of the system planning committee in 1923. Methods of analyzing population growth, load growth, and system requirements were devised, which, in their expanded state, are still in effect today. Later promotions brought him successively the positions of assistant manager of operation and chief engineer, and in 1945, he was elected a vice-president of the company. Chairman of the AIEE Los Angeles Section 1929–30, he was AIEE vice-president, representing the Pacific District, 1935–37, and a member of the power generating committee, 1935–41, and the special committee on registration of engineers, 1942–46. Chairman of the Pacific Southwest Power Interchange Committee since 1943, he is a member of the Pacific Astronomical Society, the American Association for the Advancement of Science, and Tau Beta Pi, honorary engineering society. He also has been associated with the Edison Electric Institute, the International Conference on Large Electric High-Voltage Systems (CIGRE), and the Pacific Coast Electric Association, the last since its founding in 1916.

H. E. Farrer (A '21, M '46), assistant to the national secretary of the AIEE, and secretary of both the AIEE Standards committee and the AIEE board of examiners, has been retired. He was a member of the AIEE headquarters staff in New York, N. Y., since 1915. Born in Brooklyn, N. Y., October 4, 1883, Farrer received his degree in electrical engineering from Columbia University in 1908. For the first two years following his graduation, he held miscellaneous positions in the electrical and other fields, but in 1910, he joined the Sprague Electric Works of the General Electric Company where he remained for five years, working as technical assistant in advertising, publications, and sales. Farrer joined the headquarters staff in 1915 as assistant to the editor of AIEE publications, and was engaged in all phases of Institute publications until 1918. He then was appointed as secretary to the AIEE board of examiners, one of the positions he held until retiring. Farrer's duties included the preparation and presentation of all applications for admission to the Institute and for transfer to the higher grades. In 1923, he added the duties of the secretary of the Standards committee to his staff responsibilities, including the presentation of all Standards matters at committee meetings, preparation and publication of reports, Standards, and codes, and the general administration of Standards activities. As part of his duties in this capacity, Farrer also acted as AIEE representative to the electrical Standards committee of the American Standards Association, and served as alternate for the Institute on the Standards Council. Since 1918, he has been the AIEE headquarters representative on the New York winter meeting committees. From its formation in 1919, he also has served as AIEE headquarters representative to the New York Section. For the past ten years, Farrer has been a director of the board administrating the New York City office of the Engineering Societies Personnel Service. Though retired from active duty with the AIEE, Farrer will remain active in electrical engineering affairs as secretary of the New York Electrical Society.

J. J. Anderson, Jr. (A '40), formerly assistant to H. E. Farrer, and also secretary of the American Standards Association sectional committee *C42*, AIEE headquarters, New York, N. Y., has been named to replace Farrer as secretary to both the AIEE board of examiners and the AIEE Standards committee. Born February 19, 1916, in New York, N. Y., Anderson received his bachelor of electrical engineering degree from the Pratt Institute, Brooklyn, N. Y., in 1939. He joined the AIEE headquarters staff in 1940, following employment as a sales engineer trainee in the New York City offices of the United States Rubber Company. Enlisting in the United States Navy in 1943, Anderson served in the rank of lieutenant, taking part in the first assault waves on the Normandy and southern France beachheads. In his

H. J. Scholz

E. W. Davis

N. B. Hinson

H. E. Farrer

J. J. Anderson

new position, Anderson will be responsible for the administrative details connected with the work of the Standards committee, including the preparation of material for presentation at committee meetings, and publication of reports on proposed Standards, test codes, and approved Standards. As secretary to the board of examiners, he also will review personally all membership and change of membership status applications prior to their presentation to the board, as well as handling all correspondence involved in that work. In addition, as AIEE headquarters representative on the executive committee of the New York Section, he will act as liaison between headquarters and the activities of the Section.

OBITUARY ....

Othmar Karl Marti (A '21, M '27, F '39), consulting engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., died February 15, 1949. Born May 23, 1891, in Frick, Switzerland, he was graduated from the Polytechnic Institute in Zurich in 1916. With Brown, Boveri and Company, Baden, Switzerland, for the next four years, he assisted in the design of synchronous motors and generators, and helped to develop a voltage regulator that later was introduced into this country. Coming to the United States in 1921, he joined the Heckscher Research Foundation, Cornell University, Ithaca, N. Y., where he aided in the development of mathematical analyzing devices, and three years afterwards, he became an instructor of electrical engineering at the same university. In 1926, he was employed by the American Brown Boveri Electric Corporation, Camden, N. J., as a consulting engineer, one year later, being appointed chief engineer of the application design and development departments. Moving to Milwaukee in 1931, he joined the Allis-Chalmers Company, where he was made engineer in charge of rectifier equipment. Named a consulting engineer by the company in 1940, some of his achievements include: the development of a pool-type mercury-arc rectifier; the design of phase multiplication networks preventing telephone interference in large rectifier plants; the conducting of one of the first field tests on high-voltage circuit breakers under actual short-circuit conditions; and the investigation of power equipment suitable for electromagnetic separation of uranium isotopes, as well as the development of other devices for the Manhattan Engineering District Project. A holder of several patents, he wrote many articles which appeared in AIEE *TRANSACTIONS* as well as books on d-c machines and mercury-arc power rectifiers. A member of two AIEE committees, electric machinery, 1928–30 and 1932–43, and electronics, 1942–43, he also was affiliated with the American Electric Railway Engineering Association, the Franklin Institute, the National Electric Light Association, and the Engineering Society of America.

Keith Langdon Maurer (M '30), electrical engineer, Bell Telephone Laboratories, New York, N. Y., died February 23, 1949. Born October 20, 1895, at Garnaville, Iowa, he received a bachelor of science degree in 1917 from Amherst College and a bachelor of philosophy degree four years later from Yale University. After working for the General Electric Company and Albert F. Ganz, Inc., Maurer joined the research department of the American Telephone and Telegraph Company in 1925, a department that later became part of the Bell Telephone Laboratories. For most of his 24 years with the Bell system, he specialized in methods of protecting telephone transmission systems from inductive interference from electrified railways and power systems. During the recent war, he turned to the development of countermeasures in the field of radio navigation, later, adding to his duties, the prevention of electrolytic corrosion in cables. Another of his wartime activities was the setting up of the civilian defense communication system for Nassau County on Long Island. In recognition of this service, he was made a member of Tau Beta Pi, national honorary engineering fraternity. Other scientific societies with which he was affiliated include: the Institute of Radio Engineers, the Association of American Railroads, the National Association of Corrosion Engineers, the American Association for the Advancement of Science, the Yale Engineering Society, and Sigma Xi, honorary science research fraternity. Maurer served in the Navy during the first World War.

Jesse Lysander Thompson (M '40), design engineer, Imperial Irrigation District, Imperial, Calif., died January 13, 1949. Born July 21, 1887, in Lyra Township, Blue Earth County, Minn., he attended the University of Minnesota. Postponing the completion of his education when he was half-way through college, he worked four years for several Minnesota electrical utilities. Elected to Tau Beta Pi, honorary engineering society, he was graduated in 1917. After two years as assistant superintendent with the Minnesota and Ontario Paper Company, International Falls, Minn., he joined the San Joaquin Light and Power Corporation, Bakersfield, Calif., as chief substation inspector. In 1929, he began a 15-year association with the Kelman Electric and Manufacturing Company, Los Angeles, Calif., as electrical engineer. Many improvements on high-voltage oil circuit breakers and switchgear were the result of Thompson's contributions during this period. Confidential work on the design of apparatus for the United States Air Corps occupied him in the years 1944–46. He became affiliated with the Imperial Irrigation District immediately following his war work. Thompson was a member of the Society of Automotive Engineers and the American Society of Mechanical Engineers.

Raymond K. Law (A '47), electrical engineer, power utilization division, United States Bureau of Reclamation, Denver, Colo., died February 23, 1949. A native of Summerfield, Kans., he was born August 20, 1902. After graduating from Tarkio College in 1925, with a bachelor of science degree, he joined the Kelso-Burnett Electric Company, Chicago, Ill., as an electrician. In 1934, he established an electrical contracting and repair business in Fort Morgan, Colo., which he operated for eight years. On the staff of the United States Bureau of Reclamation from 1942 until the time of his death, he worked on the Green Mountain Power Plant as plant electrician, and was transferred later to the power section of the Denver office. Law was a member of the United States Bureau of Reclamation Technical Club.

Otis Allen Kenyon (A '06, M '16), chairman of the board, Kenyon and Eckhart Inc., New York, N. Y., died February 3, 1949. Born in 1879 in Baldwinsville, N. Y., Kenyon was educated both abroad and in this country. Returning from his studies in Paris, France, he entered Cornell University where he received his mechanical engineering degree in 1901. After further schooling in Berlin, Germany, he went to St. Louis, Mo., in 1904, to become a member of the Railway Test Commission of the World's Fair. In 1905, he joined the McGraw-Hill Publishing Company, as editor, his duties being the approval and editing of manuscripts. While there, he was also coauthor and editor of the "Standard Handbook for Electrical Engineers," his responsibility for the book continuing through the first three editions. In the years, 1910–11, he worked with Doctor Edward Weston of the Weston Electrical Instrument Company, preparing technical articles on new types of apparatus. During the next two years, Kenyon abstracted and compiled an index of all the "Proceedings" published by the AIEE from 1881 to 1910. In World War I, he gained prominence as a welding expert, inventing the welding systems used in the manufacture of Liberty engines used for aircraft and in the steel lining of the Catskill Aqueduct, a part of New York City's water system. In all, he took out about 65 patents related to arc welding. Kenyon entered the field of advertising in 1919 via a technical agency, the Ray D. Lillibridge Company, New York, N. Y. Ten years later, he helped to organize the advertising firm of Kenyon and Eckhart Inc., starting as chairman and director, and becoming chairman of the board in 1942. A translator of several French and German technical books, he was also chairman of the board of the Kenyon Technical Research Foundation, Greenwich, Conn. Other societies of which Kenyon was a member were the Society of Automotive Engineers and the American Association for the Advancement of Science.

Kenneth Howard Sloan (A '38, M '47), a senior engineer with the Office of Supervisor of Shipbuilding, United States Navy, New York, N. Y., died December 31, 1948. Born in McComb, Miss., in 1897, Sloan received his technical education in the same state, attending the University of Mississippi. Following his graduation in 1918, he was employed by the Westinghouse Electric Corporation, East Pittsburgh, Pa., his duties being largely those of a test engineer. In 1920, the Westinghouse company transferred him to its New York service department, and from that time until last year Sloan worked in the New York City area. During the years 1922–25, he was employed by two metropolitan power companies, first by the Brooklyn Edison Company, and

later by the Queensborough Gas and Electric Company, his responsibilities in both firms being related to customer service. Employed by Thomas E. Murray Inc., in 1925, as a diagram draftsman, he was promoted later to field supervisor. After five years, he joined the Erikson Equipment Company as an engineer in charge of New York Subway Board of Transportation contracts. Sloan went to work for the Office of Shipbuilding in 1934 as a senior electrical engineer. His duties included the approving of apparatus for all naval vessels designed in the New York area, the development of high shock equipment, and promulgating test memoranda for the testing of electric apparatus on shipboard. He held this position at the time of his death.

Walter F. Smith, Jr. (A '23, M '32), apparatus development department, Bell Telephone Laboratories, Inc., Murray Hill N. J., died February 9, 1949. Born in New York, N. Y., in 1896, he was an alumnus of Cooper Union. In 1914, he joined the engineering department of the Western Electric Company, which later became the Bell Telephone Laboratories. By the time he had completed his night electrical engineering course, 1922, he had become an assistant engineer, conducting investigations in connection with the difficulties encountered in the manufacture of telephone transmitters and receivers. During the next three years, he was a full-fledged engineer, in charge of a testing crew making articulation tests on telephone instruments. In later years, Smith assisted in the design of acoustic devices, and equipment to measure the frequency characteristics of telephones. He helped to develop such apparatus as voice silencers, antinoise transmitters, and airplane transmitters, receiving two patents as the result of some of his work. Smith was a colonel in the Army Signal Corps during the war, serving as an executive officer in the ground signal maintenance agency in Philadelphia, Pa., later being transferred to the South Pacific on assignment from the chief signal officer. At the time of his death, he was commanding officer of the 181st Signal Reserve Group.

Harry Douglas Garretson (A '07, M '33, ML '42), consulting engineer, Stevens, Jordan and Harrison, New York, N. Y., died February 12, 1949. A native of Buffalo, N. Y., he was born in 1881, and attended Cornell University. After receiving his degree in electrical engineering in 1905, he went to work for the Eastman Machine Company in his home town. His duties in that firm, and the three other companies that he worked for during the next six years of his career, were related to the design of portable electric tools and elevator motors. In 1911, he was in New York, N. Y., employed by H. P. Hill, consulting engineer, and working with high-tension transformers, synchronous motors, and rectifiers. Employed by Waite and Bartlett also of New York, in 1913, as vice-president in charge of research, he applied his knowledge of motors and transformers to the design of X-ray equipment. During World War I, Garretson designed the Army Bedside Unit, an X-ray outfit for field hospitals. In 1930 Waite and Bartlett appointed him chief engineer. He served with that company for more than three decades.

Thomas H. Long (M '44), research department, C. G. Conn, Ltd., Elkhart, Ind., died January 18, 1949. Born September 14, 1905, in Wakeeney, Kans., Long received his engineering degree at Kansas State College, Manhattan, Kans., in 1927. Following his graduation, he joined the Westinghouse Electric Corporation. After taking the company's student course for one year, he did design and development work on coreless induction furnaces. From 1930–33, Long's duties were the design of electronic industrial equipment, mainly photoelectric devices. He joined the C. G. Conn, Ltd., in 1942, working on projects related to aviation gyros, bomb-release problems, and telemetering, until his death. Long was a member of the AIEE basic sciences committee, 1948–49.

Matthew Xavier Moser (A '25, M '44), plant protection engineer, Wisconsin Telephone Company, Milwaukee, died February 3, 1949. Born in Wabasha, Minn., in 1901, he was an alumnus of Marquette University. After receiving his electrical engineering degree in 1924, he joined the Wisconsin Telephone Company in Milwaukee as a central office inspector. Promotions in that company brought him the positions of transmission supervisor, foreign wire relations engineer, and plant protection engineer. His latest work was concerned with noise and crosstalk problems, inductive and structural co-ordination, as well as plant protection.

William M. White (M '21), retired hydraulic engineer, Coral Gables, Fla., died February 9, 1949. A native of Valley Head, Ala., born in 1871, he attended the University of Alabama for a year and received a bachelor of science degree from Tulane University in 1899. During the next few years, he was assistant engineer in charge of a Drainage Commission steam generating station in New Orleans, La. Later, he moved to Philadelphia, Pa., where he worked for the I. P. Morris Company, assisting in the design, construction, and testing of waterwheels for driving electric generators. White's association with the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., began in 1911 and lasted 31 years. As head of the hydraulic department, he supervised the design of hydraulic turbines used in the hydroelectric plants of Niagara Falls, Conowingo, the Tennessee Valley Authority, Hoover Dam, and Shasta Dam. In 1930, White received an honorary doctorate of science from Tulane University and, ten years later, a special Modern Pioneer award from a committee of scientists headed by Doctor Karl T. Compton, president of the Massachusetts Institute of Technology. The latter was presented to him for his invention of the Hydraucone draft-tube regainer, a device which improved flow in hydraulic turbine draft tubes. A holder of many patents related to hydraulics, White wrote numerous articles, not only about his engineering specialty, but about his travels in the head-hunting regions of Formosa. He prepared a report on that country for the War Department during the recent war. A life member of the American Society of Civil Engineers, White was former president of the Milwaukee Engineers Society, and a member of the American Society of Mechanical Engineers, as well as past chairman of the Hydraulics Corporation of America. He belonged to the AIEE power generation committee in the years 1924 and 1927–29.

Adam Pen-Tung Sah (A '35, F '45), secretary general, Academica Sinica, Nanking, China, died February 14, 1949. A graduate of Tsing Hua College, Peiping, China, Sah was born in Foochow in 1902. Coming to the United States, he obtained a mechanical engineering degree from Leland Stanford Junior University in 1924, and an electrical engineering degree from Cornell University the following year. He was granted a doctor of science degree from the latter school three years later. Upon completing his graduate work, Sah joined the research and development department of the Westinghouse Electric Corporation, in East Pittsburgh, Pa., after which he returned to China to become an assistant professor at Tsing Hua University. A full professor in 1930, he was granted leave of absence to work with the National Peking University. Back in this country, six years later, he was a visiting professor of electrical engineering at Ohio State University, where he did some of his well-known work on dyadic methods of circuit analysis. He wrote many papers on this topic, as well as related subjects, many of which appeared in the AIEE *TRANSACTIONS*. In the year that Japan set up a so-called independent government in Peiping (1937), Sah returned to China to head the National University of Amoy. Responsible for the transfer of the university's facilities to Changting to the western part of Fukien province in the face of the Japanese attack, he also helped to develop and install the school's engineering departments. This task occupied him through most of the war.

Thomas O. Moloney (A '12, M '21, F '45, ML '47), chairman of the board of directors of the Moloney Electric Company, St. Louis, Mo., died January 30, 1949. Born in 1872 in Jerseyville, Ill., he studied electrical engineering in St. Louis. In the latter city in 1890, he joined the electrical department of the Laclede Gas Light Company. Seven years later, Moloney with his brother-in-law, the late James J. Mullen, founded the Moloney Electric Company. Their firm was the first in America to use low-loss nonaging silicon steel commercially for transformer cores. In the early 1900's the properties of the new material seemed so incredible that it was necessary on a few occasions for the company to post bond guaranteeing its performance. The final result was the adoption of the use of silicon steel in transformers by most manufacturers. Under Moloney's direction, the company also developed the interlaced winding as a method of balancing the loading on single-phase transformers when used for 3-wire service. Among the first to use oil as a cooling and insulating medium in transformers, his firm also developed the resistance method of determining winding temperature rise. A member of the Na-

tional Electrical Manufacturer's Association, Moloney also belonged to the Electrical Manufacturers' Club.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners at its meeting of February 17, 1949, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Fleming, G. A., chief, regional div. power resources & development, U. S. Bureau of Reclamation, Sacramento, Calif.
Jack, H., chief elec. engr., British Thomson-Houston Co., Ltd., Rugby, England

2 to grade of Fellow

To Grade of Member

Atkinson, R. G., distribution engr., Public Service Co. of Colorado, Denver, Colo.
Berger, R., elec. engr., J. C. Penney Co., New York, N. Y.
Bliss, D. S., vice pres., Bliss Electrical School, Takoma Park, Md.
Boyd, A. G., switchgear specialist, General Elec. Co., Cleveland, Ohio
Brightfelt, J. C., supt. of inspection & test, General Elec. Co., Erie, Pa.
Calkins, R. L., power engr., Pennsylvania Salt Mfg. Co., Wyandotte, Mich.
Davis, A. H., elec. engr., U. S. Bureau of Reclamation, Denver, Colo.
Fishbeck, C. E., staff engr., The Detroit Edison Co., Detroit, Mich.
Garretson, H. W., elec. engr., U. S. Bureau of Reclamation, Denver, Colo.
Gegenheimer, W. C., senior elec. engr., Western Electric Co., Winston-Salem, N. C.
Goldsworthy, F. R., mayor, City of North Vancouver; elec. supt., Burrard Drydock Co., Ltd., North Vancouver, British Columbia, Canada
Gray, D., engr., Westinghouse Elec. Corp., New York, N. Y.
Hall, R. G., div. transmission engr., American Tel. & Tel. Co., Denver, Colo.
Herzberger, F. H., head office div., elec. dist. engg. dept., Public Service Co. of Colorado, Denver, Colo.
Hofer, Harold T., head, construction div., elec. dist. dept., Public Service Co. of Colo., Denver, Colo.
Hoover, A. J., elec. engr., U. S. Bureau of Reclamation, Denver, Colo.
Huffer, C., relay engr., Florida Power Corp., St. Petersburg, Fla.
Kezer, J., elec. engr., U. S. Bureau of Reclamation, Denver, Colo.
Leeds, T. A., elec. engr., The Commonwealth & Southern Corp., Jackson, Mich.
Leeming, H. H., elec. engr., United Merchants Laboratories, Inc., New York, N. Y.
Mayberry, F. C., chief engr., Canadian National Exhibition Grounds, Toronto, Ontario, Canada
McMahon, E. V., system study engr., Southern Engineering Co., Atlanta, Ga.
Morisuye, M., transformer design engr., Westinghouse Elec. Corp., Sharon, Pa.
Ramaley, E. J., research engr., Battelle Memorial Institute, Columbus, Ohio
Reizenstein, H. S., Jr., design engr., Westinghouse Elec. Corp., Sharon, Pa.
Sibila, K. F., acting head, elec. engg. dept., University of Akron, Ohio
Tucker, W. H., section engr., recording instrument engg. section, General Elec. Co., Lynn, Mass.
Webb, F. G., supervising engr., Commonwealth Edison Co., Chicago, Ill.
Wentz, J. K., acting insulation section head, L & CE lab., General Electric Co., Erie, Pa.
York, V. O., prof. elec. engg., Michigan College of Mining & Engg., Houghton, Mich.

30 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before April 21, 1949, or June 21, 1949, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Allibone, T. E., Associated Elec. Industries, Ltd., Aldermaston, Berkshire, England
Case, A. E., Elec. Power Board, Nashville, Tenn.

2 to grade of Fellow

To Grade of Member

Ackerman, A. J., COBAST, c/o São Paulo Tramway Light & Power Co. Ltd., São Paulo, Brazil, South America
Ahmed, W., Harris J. Ryan High Voltage Lab., Stanford Univ., Stanford, Calif.
Beall, M. F., Bonneville Power Admin., Portland, Oreg.
Benson, R. J., (re-election), Wagner Elec. Corp., St. Louis, Mo.
Chaput, H., English Elec. Co. of Canada, St. Catharines, Ontario, Canada
Cherksey, A. C., Elec. Heating Equipment Co., Philadelphia, Pa.
Cowan, J. A., North of Scotland Hydro-Elec. Board, Pitlochry, Perthshire, Scotland
Crabtree, K. G., Univ. of Maine, Orono, Maine
Cronberger, L. C., Public Service Co. of Oklahoma, Tulsa, Okla.
Dixon, W. R., (re-election), Westinghouse Elec. Corp., Ft. Worth, Tex.
Dutschmann, K. T., N. Y. Tel. Co., Brooklyn, N. Y.
Fouts, B. S., Dept. of the Army, Tokyo Comm. Center, c/o P. M., San Francisco, Calif.
Garbutt, W. D., The Hackbridge & Hewittic Elec. Co. of Canada, Ltd., Montreal, Quebec, Canada
Gaudet, M. J. G., Bell Tel. Co. of Canada, Montreal, Quebec, Canada
Goris, W. R., Purdue Univ., Lafayette, Ind.
Griffith, H. C., Jr., General Elec. Co., Erie, Pa.
Guess, B. L., Jr., 424 S. Staples St., Corpus Christi, Tex.
Hammond, R. L., General Elec. Co., Schenectady, N. Y.
Hodges, R. E., Appalachian Elec. Power Co., Charleston, W. Va.
Hout, H. B., Appalachian Elec. Power Co., Huntington, W. Va.
Hughes, J. M., Pennsylvania Elec. Co., Altoona, Pa.
King, A. N., Broadway Maintenance Corp., Long Island City, N. Y.
Lang, J. A., Scott Whitnah, Lang & Asso., Inc., Minneapolis, Minn.
MacVaugh, H., Jr., Philadelphia Elec. Co., Philadelphia, Pa.
Marshall, L. G., Westinghouse Elec. Int'l. Co., New York, N. Y.
McAdam, J. E., Dixie Elec. Membership Corp., Baton Rouge, La.
Moran, L. L., The Dow Chemical Co., Midland, Mich.
Nodelman, H. M., R. C. A. Institutes, Inc., New York, N. Y.
Odmark, A. L., Servo Corp. of America, New Hyde Park, L. I., N. Y.
Page, H. F., (re-election), American Tel. & Tel. Co. Chicago, Ill.
Parker, E. E., General Elec. Co., Schenectady, N. Y.
Pique, Z. W., Westinghouse Elec. Supply Co., Johnstown, Pa.
Spry, R. W., Stone & Webster Engg. Corp., Boston, Mass.
Stanton, C. H., Orlando Utilities Comm., Orlando, Fla.
Steiling, W. J., Jr., Anheuser-Busch, Inc., St. Louis, Mo.
Stillman, H. D., Appalachian Elec. Power Co., Huntington, W. Va.
Talley, C. B., Appalachian Elec. Power Co., Charleston, W. Va.
Wagschal, G., George Wagschal Associates, Detroit, Mich.
Weston, D. E., Allis-Chalmers Mfg. Co. Inc., West Allis, Wis.
Young, W. H., Elec. Service Mfg. Co., Philadelphia, Pa.

40 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

1. North Eastern

Ammons, E. E., General Elec. Co., Schenectady, N. Y.
Amorosi, R. J., Cornell Univ., Ithaca, N. Y.
Anderson, D. H., General Elec. Co., Schenectady, N. Y.
Anfenger, E., General Elec. Co., Bridgeport, Conn.
Armstrong, J. W., New England Tel. & Tel. Co., Boston, Mass.
Aucella, A. J., Boston Edison Co., Revere, Mass.
Autrey, F. E., General Elec. Co., Schenectady, N. Y.
Band, H. E., General Elec. Co., West Lynn, Mass.
Barber, J. W., Jr., General Elec. Co., Schenectady, N. Y.
Beauregard, R. E., Boston Edison Co., Boston, Mass.
Beers, W. A., New England Tel. & Tel. Co., Boston, Mass.
Bell, H. L., Jr., General Elec. Co., Pittsfield, Mass.
Berghoff, R. R., General Elec. Co., Pittsfield, Mass.
Berman, M., General Elec. Co., Schenectady, N. Y.
Blackmon, S. C., General Elec. Co., Schenectady, N. Y.
Blake, R. F., General Elec. Co., Schenectady, N. Y.
Bono, C., General Cable Corp., Frankfort, N. Y.
Booth, T. H., 8 School St., Saranac Lake, N. Y.
Born, R. N., Ward Leonard Elec. Co., Rochester, N. Y.
Bosselman, W. E., Gibson Engg. Co., Boston, Mass.
Boswell, P. B., General Elec. Co., Schenectady, N. Y.
Bouton, D. M., General Elec. Co., Pittsfield, Mass.
Branflick, R. A., General Elec. Co., Pittsfield, Mass.
Brenner, M. A., General Elec. Co., Fitchburg, Mass.
Brown, G. R., Intl. General Elec. Co., Schenectady, N. Y.
Brown, N. W., General Elec. Co., Schenectady, N. Y.
Buchen, J. F., General Elec. Co., Lynn, Mass.
Burck, S., General Elec. Co., Schenectady, N. Y.
Burkhardt, K. R., New England Machine & Elec. Co., Pawtucket, R. I.
Burmaster, C. E., N. Y. Power & Light Corp., Fort Johnson, N. Y.
Caggiano, A. J., Northeastern Univ., Boston, Mass.
Callahan, J. J., General Elec. Co., Pittsfield, Mass.
Carella, D. J., General Elec. Co., Schenectady, N. Y.
Carroll, J. H., Electro Metallurgical Div., Niagara Falls, N. Y.
Carson, A. B., Jr., General Elec. Co., Schenectady, N. Y.
Christolear, M. D., General Elec. Co., Lynn, Mass.
Collins, F. T., Jr., General Elec. Co., Schenectady, N. Y.
Collins, G. D., General Elec. Co., Schenectady, N. Y.
Conaway, C. W., Factory Insurance Assn., Hartford, Conn.
Cooke, H. F., Syracuse Univ., Syracuse, N. Y.
Cornelison, R. C., General Elec. Co., Lynn, Mass.
Coyne, J. F., New England Tel. & Tel. Co., Boston, Mass.
Credit, J. H., Worcester County Elec. Co., Worcester, Mass.
Crispin, W. L., General Elec. Co., Schenectady, N. Y.
Crumbley, J. W., General Elec. Co., Schenectady, N. Y.
Davis, M., Joy Mfg. Co., Claremont, N. H.
Decker, E. N., Jr., General Elec. Co., Schenectady, N. Y.
Delaney, F. H., Jr., I. B. M. Co., Hartford, Conn.
Derewianka, N., Connecticut Power Co., New London, Conn.
Desaulniers, G. E., II, General Elec. Co., Pittsfield, Mass.
De Vault, E. N., General Elec. Co., Schenectady, N. Y.
Dickinson, R. W., General Elec. Co., Lynn, Mass.
Draper, A. B., General Elec. Co., Schenectady, N. Y.
Duff, R. F., Eastman Kodak Co., Rochester, N. Y.
Dunham, L. J., Jr., Franklin Tech. Inst., Boston, Mass.
Eargle, V. H., General Elec. Co., Brockport, N. Y.
Edlund, L. A., Jr., General Elec. Co., Lynn, Mass.
Ellis, J. P., General Elec. Co., Pittsfield, Mass.
Erickson, J. M., Public Service Comm. of N. Y. State, New York, N. Y.
Evans, M. R., Allis-Chalmers Mfg. Co., Boston, Mass.
Ezen, J. N., Jackson & Moreland, Boston, Mass.
Fallon, J. T., Jr., General Elec. Co., Schenectady, N. Y.
Feder, B., General Elec. Co., Pittsfield, Mass.
Feldman, D. T., Hamilton Standard Propellers, E. Hartford, Conn.
Fierberg, I. M., Merris A. Fierberg Co., Hartford, Conn.
Ford, J. L., General Elec. Co., Syracuse, N. Y.
Forney, J. F., Standard Shade Roller Corp., Ogdensburgh, N. Y.
Franz, R. N., Jr., E. I. DuPont Co., Niagara Falls, N. Y.
Frederick, G. E., General Elec. Co., Pittsfield, Mass.
Geibel, J. P., General Elec. Co., Pittsfield, Mass.
Gerard, V. L., General Elec. Co., Pittsfield, Mass.
Gleichman, R. F., General Elec. Co., Pittsfield, Mass.
Gochenour, O. C., General Elec. Co., Schenectady, N. Y.
Gorman, F., General Elec. Co., Schenectady, N. Y.
Gottliebsen, L. H., General Elec. Co., Schenectady, N. Y.
Granfors, W. H., Carrier Corp., Syracuse, N. Y.
Grauch, W. F., (re-election) Buffalo Niagara Elec. Corp. Buffalo, N. Y.
Gregory, J. G., General Elec. Co., Schenectady, N. Y.
Greunke, O. V., Sylvania Elec. Prod. Inc., Boston, Mass.
Grove, J. F., Rhode Island State College, Kingston, R. I.
Hansberry, J. H., General Elec. Co., Schenectady, N. Y.
Harshbarger, C. K., Jr., E. I. DuPont De Nemours & Co., Buffalo, N. Y.
Henchy, W. C., General Elec. Co., Schenectady, N. Y.
Herder, D. J., General Elec. Co., Lynn, Mass.
Higgins, T. G., General Elec. Co., Schenectady, N. Y.
Hoch, F. J., General Elec. Co., Pittsfield, Mass.
Hogan, E. V., Jr., General Elec. Co., Syracuse, N. Y.
Holter, W. G., General Elec. Co., Pittsfield, Mass.
Houghton, R. H., General Elec. Co., Boston, Mass.
Husher, R. W., Jr., Pratt & Whitney Aircraft, E. Hartford, Conn.
Johns, N. H., Sylvania Elec. Prod. Co., Salem, Mass.
Johnson, M. H., General Elec. Co., Schenectady, N. Y.
Kao, C., Jackson & Moreland Co., Boston, Mass.
Karlberg, B. G., General Elec. Co., Schenectady, N. Y.
Keene, T. F., General Elec. Co., Lynn, Mass.
Kennedy, O. O , Jr., Worcester Polytech. Inst., Worcester, Mass.
Kent, J. T., General Elec. Co., Schenectady, N. Y.
Kieft, R. B., General Elec. Co., Schenectady, N. Y.
Kincaid, N. L. Westinghouse Elec. Corp., Buffalo, N. Y.
Klammer, A., Jr., General Elec. Co., Pittsfield, Mass.
Kling, W. A., Central Hudson Gas & Elec. Corp. Poughkeepsie, N. Y.
Koch, R. E., General Elec. Co., Schenectady, N. Y.
Kowalczyk, J. W., General Elec. Co., Schenectady, N. Y.
Krobot, R. F., General Elec. Co., Schenectady, N. Y.
Lagers, W. L., General Elec. Co., Lynn, Mass.
Landes, I. H., General Elec. Co., Schenectady, N. Y.
Landin, E. J. A., Jr., Metropolitan Transit Authority, Boston, Mass.
Lane, B. C., General Elec. Co., Schenectady, N. Y.
Larson, R. E., General Elec. Co., Lynn, Mass.
Laurent, J. A., Jr., General Elec. Co., Schenectady, N. Y.
Law, S. H., Western Massachusetts Elec. Co., Springfield, Mass.
Leibinger, G. E., General Elec. Co., Pittsfield, Mass.
Leiby, D. W., General Elec. Co., Lynn, Mass.
Leslie, J. D., General Elec. Co., Schenectady, N. Y.
Levin, B. S., General Elec. Co., Schenectady, N. Y.
Li, H. T., New England Power Service Co., Boston, Mass.
Lindsay, J. S., General Elec. Co., Lynn, Mass.
Livingston, R. G., General Elec. Co., Pittsfield, Mass.
Louden, V. J., General Elec. Co., Schenectady, N. Y.
Lucas, J. G., Jr., American Cyanamid Co., Bridgeville, Conn.
Lum, W. S., Crouse-Hinds Co., Syracuse, N. Y.
Mack, D. R., General Elec. Co., Pittsfield, Mass.
Maddock, R. B., General Elec. Co., Schenectady, N. Y.
Marcus, J. A., The Electric Indicator Co., Stamford, Conn.
McBroom, R. C., General Elec. Co., Pittsfield, Mass.
McCaig, W. J., Steele Elec. Equip. Co., Niagara Falls, N. Y.

McCaskill, K., Hooker Electrochemical Co., Niagara Falls, N. Y.
Mc Clure, E. J., Jr., Bethlehem Steel Co., Lackawanna, N. Y.
McGayhey, R. E., I. B. M. Corp., Endicott, N. Y.
McVean, J. E., N. Y. State Inst. of Applied Arts & Sciences, Binghamton, N. Y.
Merlini, A. J., Univ. of New Hampshire, Durham, N. H.
Messier, W. J., Jr., Northwestern Development Engrs., Inc., Pawtucket, R. I.
Michael, R. E., General Elec. Co., Schenectady, N. Y.
Mitchell, J. M., Jr., General Elec. Co., Schenectady, N. Y.
Moffitt, G. R., Jr., Pratt & Whitney Aircraft, E. Hartford, Conn.
Morse, R. W., Westinghouse Elec. Corp., Buffalo, N. Y.
Murphy, J. J., Boston Edison Co., Boston, Mass.
Newsom, J. H., Jr., General Elec. Co., Schenectady, N. Y.
Nikander, R. W., General Elec. Co., West Lynn, Mass.
Norton, W. I., Public Service Co. of N. H., Rochester, N. H.
Nurmela, E. A., Allis-Chalmers Mfg. Co., Hyde Park, Mass.
Oakes, V. S., General Elec. Co., Pittsfield, Mass.
Olsen, A. G., Sprague Elec. Co., North Adams, Mass.
Olson, O. H., General Elec. Co., Pittsfield, Mass.
O'Neill, K. J., General Elec. Co., Schenectady, N. Y.
Oney, W. R., General Elec. Co., Schenectady, N. Y.
Oprisch, J. L., General Elec. Co., Schenectady, N. Y.
Owen, H. J., General Elec. Co., Schenectady, N. Y.
Pandit, K. R., (student), Harvard Univ., Cambridge, Mass.
Pappas, N. C., General Elec. Co., Schenectady, N. Y.
Penske, H. W., General Elec. Co., Schenectady, N. Y.
Peterson, R. W., General Elec. Co., Lynn, Mass.
Peterson, R. W., General Elec. Co., Schenectady, N. Y.
Pfrimmer, J. G., General Elec. Co., Schenectady, N. Y.
Phillips, R. A., General Elec. Co., Schenectady, N. Y.
Poliksa, J. J., General Elec. Co., Schenectady, N. Y.
Preston, J. B., General Elec. Co., Schenectady, N. Y.
Pugh, P. F., General Elec. Co., Schenectady, N. Y.
Pywell, H. E., General Elec. Co., Lynn, Mass.
Quick, C. R., General Elec. Co., Schenectady, N. Y.
Randall, R. C., General Elec. Co., Schenectady, N. Y.
Remmers, C. C., General Elec. Co., Schenectady, N. Y.
Rhyne, E. C., Jr., Westinghouse Elec. Corp., Buffalo, N. Y.
Richmond, R. B., General Radio Co., Cambridge, Mass.
Ritchie, J., Jr., General Elec. Co., Schenectady, N. Y.
Robbins, N. P., General Elec. Co., Schenectady, N. Y.
Robins, M., United Engrs. & Constructors, Providence, R. I.
Ross, R. D., General Elec. Co., Syracuse, N. Y.
Rubin, M., General Elec. Co., Bridgeport, Conn.
Rudwick, B. H., I. B. M., Endicott, N. Y.
Ryckman, W. D., Jr., General Elec. Co., Schenectady, N. Y.
Scammon, R. B., Stultz Elec. Works, Westbrook, Maine
Schneider, W. H., Jr., General Elec. Co., Schenectady, N. Y.
Schofield, T. F., General Elec. Co., Schenectady, N. Y.
Schuster, F. W., Jr., Westinghouse Elec. Corp., Buffalo, N. Y.
Sevian, E. A., Harvey Radio Labs., Inc., Cambridge, Mass.
Shapiro, E., Crystal Research Labs., Inc., Hartford, Conn.
Sheckler, A. C., General Elec. Co., Syracuse, N. Y.
Singer, E., General Elec. Co., Schenectady, N. Y.
Skolka, K. M., General Elec. Co., Schenectady, N. Y.
Slaughter, J. E., General Elec. Co., Schenectady, N. Y.
Smith, C. J., General Elec. Co., Schenectady, N. Y.
Smith, J. S., General Elec. Co., Syracuse, N. Y.
Snyder, E. L., General Elec. Co., West Lynn, Mass.
Stanziola, T. N., General Elec. Co., Burlington, Vt.
Stern, C. M., Submarine Signal Co., Boston, Mass.
Stevenson, J. R., Jr., General Elec. Co., Schenectady, N. Y.
Stewart, J. R., Westinghouse Elec. Corp., Buffalo, N. Y.
Stimm, K. W., General Elec. Co., Schenectady, N. Y.
Sullivan, V. C., Stone & Webster Engg. Corp., Boston, Mass.
Sweetland, D. A., Rochester Gas & Elec. Co., Rochester, N. Y.
Taggart, J. M., N. Y. Tel. Co., Watertown, N. Y.
Tanigawa, G. T., General Elec. Co., West Lynn, Mass.
Thing, C. M., General Elec. Co., Pittsfield, Mass.
Tomblin, E. R., General Elec. Co., Schenectady, N. Y.
Tomko, W. C., General Elec. Co., Pittsfield, Mass.
Uhrich, E., Eastman Kodak Co., Rochester, N. Y.
Valonen, L. R., Westinghouse Elec. Corp., Boston, Mass.
Ward, D. R., Bethlehem Steel Co., Lackawanna, N. Y.
Warnock, F., Jr., General Elec. Co., Syracuse, N. Y.
Waterman, C. I., General Elec. Co., Pittsfield, Mass.
Webster, E. P., Hemphill Mfg. Co., Pawtucket, R. I.
Weick, F. H., Jr., General Elec. Co., Schenectady, N. Y.
Wheat, W. M., General Elec. Co., Schenectady, N. Y.
Whelan, R. E., General Elec. Co., Schenectady, N. Y.
Wilson, R. M., Ansco, Binghamton, N. Y.
Wimer, G. W., General Elec. Co., Pittsfield, Mass.
Zembaty, S. A., General Elec. Co., Pittsfield, Mass.
Zulalian, V. C., Boston Edison Co., Boston, Mass.
Zwicker, L. P., Boston Naval Shipyard, Boston, Mass.

2. Middle Eastern

Ailes, W. B., Monarch Machine Tool Co., Sidney, Ohio
Akre, R. C., Bailey Meter Co., Cleveland, Ohio
Albers, L. R., Rural Electrification Admin., Washington, D. C.
Alley, W. T., Baldwin Locomotive Works, Eddystone, Pa.
Ambrose, J., 103 Birmingham Terr., Toledo, Ohio
Ames, E. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Anderson, G. M., Carnegie Inst. of Tech., Pittsburgh, Pa.
Anderson, R. G., Duquesne Light Co., Pittsburgh, Pa.
Andree, D. R. D., General Elec. Co., Philadelphia, Pa.
Appleman, C. G., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Arberman, J., Sperry Gyroscope Co., Cleveland, Ohio
Archer, O. J., The Elec. Controller & Mfg. Co., Cleveland, Ohio
Armstrong, W. M., Westinghouse Elec. Corp., Sharon, Pa.
Aston, T., Hazard Insulated Wire Works, Wilkes-Barre, Pa.
Auffenorde, J. E., Pittsburgh Plate Glass Co., Creighton, Pa.
Aul, W. R., Dravo Corp., South Heights, Pa.
Bain, R. J., Boone County Coal Corp., Sharples, W. Va.
Baldrige, R. R., United Engg. & Fdy. Co. Pittsburgh, Pa.
Bayley, W. G., Baldwin Locomotive Works, Philadelphia, Pa.
Bean, R. H., Westinghouse Elec. Corp., Pittsburgh, Pa.
Beckett, W. H. C., General Elec. Co., Cleveland, Ohio
Bergeron, W. L., Elliott Co., Jeannette, Pa.
Birnkrant, H. P., 7107 Harrison Ave., Pittsburgh, Pa.
Blade, R. J., Cleveland Airport, Cleveland, Ohio
Blake, J. H., Philadelphia Elec. Co., Philadelphia, Pa.
Bliss, T. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Blumenthal, D., Line Material, Zanesville, Ohio
Boettinger, H. M., Chesapeake & Potomac Tel. Co., Baltimore, Md.
Bonaccorsi, J. R., Philco Corp., Philadelphia, Pa.
Boop, W. E., Ordnance Research Lab., State College, Pa.
Bourne, D. A., Glenn L. Martin Co., Middle River, Md.
Brandon, C. N., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Breeding, D. C., Frigidaire Div. of General Motors, Dayton, Ohio
Brewer, H. K., Westinghouse Elec. Corp., Pittsburgh, Pa.
Brockert, P. E., Aeroproducts Div. G. M. C., Dayton, Ohio
Brownfield, W. N., American Tel. & Tel. Co., Philadelphia, Pa.
Bruch, R., Sylvania Elec. Products, Inc., Huntington, W. Va.
Brueckmann, R. E., Natl. Bureau of Standards, Washington, D. C.
Bucci, A. A., Glenn L. Martin Co., Baltimore, Md.
Burgess, C. W., Elec. Controller & Mfg. Co., Cleveland, Ohio
Burke, C. F., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Cannon, W. R., 3516 W. Place N. W., Washington 7, D. C.
Carey, A. J., Union Switch & Signal Co., Swissvale, Pa.
Carlson, P. O., Univ. of Delaware, Newark, Del.
Caruso, H. E., Cleveland Elec. Illumination Co., Cleveland, Ohio
Chabot, F. E., General Electric Co., Philadelphia, Pa.
Chambers, W. N., Jr., Dayton Power & Light Co., Dayton, Ohio
Chosky, P., Audovox Sound, Pittsburgh, Pa.
Clark, G. E., Jr., 3700 Sansom, Philadelphia, Pa.
Clark, J. J., Jr., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Cleland, C. E., Westinghouse Elec. Corp., Pittsburgh, Pa.
Cloer, J. H., Jr., Toledo Edison Co., Toledo, Ohio
Cochran, K. E., Battelle Memorial Inst., Columbus, Ohio
Costanzo, S. P., Signal Corps Procurement Agency, Philadelphia, Pa.
Craig, T. J., Carl J. Long, Pittsburgh, Pa.
Cramp, J. B., Firestone Tire & Rubber Co., Akron, Ohio
Creelman, W. K., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Cretiz, W. M., Jr., Metropolitan Edison Co., Reading, Pa.
Curry, F., Union Switch & Signal Co., Swissvale, Pa.
Custer, R. E., The Glenn L. Martin Co., Middle River, Md.
Day, H. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Day, V. O., Jr., USAF, Wright-Patterson AFTB, Dayton, Ohio
Delforge, J. F., Carbide & Carbon Chem. Corp., South Charleston, W. Va.
Dille, J. G., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Dinkel, J. W., Taylor Elevator Service Co., Cleveland, Ohio
Dobbins, B. D., Johns Hopkins Univ., Silver Spring, Md.
Dobbins, P. J., Jr., General Elec. Co., Martins Ferry, Ohio
Dodge, D. D., Owens-Illinois Glass Co., Toledo, Ohio
Downs, C. L., Jr., Pennsylvania Power & Light Co., Allentown, Pa.
Duffett, C. W., Jr., The Elec. Controller & Mfg. Co., Cleveland, Ohio
Eichner, K. D., Carnegie-Illinois Steel Corp., Homestead, Pa.
Eikner, D. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Eisenhard, S. E., Jr., Bell Tel. Co. of Pa., Harrisburg, Pa.
Eiserloh, N. A., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Elliott, R. T., General Elec. Co., Philadelphia, Pa.
Emerson, L. F., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Enright, J. A., General Elec. Co., Philadelphia, Pa.
Erickson, A. E., General Elec. Co., Erie, Pa.
Falkowski, E. H., R.E.A., Washington, D. C.
Farnham, F. R., Gibson Elec. Co., Pittsburgh, Pa.
Fasnacht, R. J., Duquesne Light Co., Pittsburgh, Pa.
Feldt, B. F., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Fetterole, P. A., Ohio Public Service Co., Alliance, Ohio
Finley, R. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Finn, H. L., Elec. Auto-Lite Inc., Cincinnati, Ohio
Flowers, R. G., Jr., General Elec. Co., Philadelphia, Pa.
Flugum, R. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Forbes, T. J., Rural Electrification Admin., Washington, D. C.
Fortune, G. T., Erie Resistor Corp., Erie, Pa.
Foster, J. M., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Freppel, F. N., *WSPD-TV*, Toledo, Ohio
Freudenberg, M. C., Westinghouse Elec. Corp., Washington, D. C.
Frick, R. E., General Elec. Co., Philadelphia, Pa.
Fried, W. R., U. S. A. F., Wright Field, Dayton, Ohio
Fritz, E. H., Kennametal, Inc., Latrobe, Pa.
Frutchey, W. W., Stockwall Transformer Corp., Akron, Ohio
Gale, R. P., American Rolling Mill Co., Butler, Pa.
Galiyano, M. C., Pennsylvania Power & Light Co., Allentown, Pa.
Gardner, M. F., Toledo Edison Co., Toledo, Ohio
Gellert, M. E., The Glenn L. Martin Co., Baltimore Md.
George, H. K., Westinghouse Elec. Corp., E. Pittsburgh Pa.
Gerbin, P. N., Carnegie-Illinois Irvin Works, Monessen, Pa.
Giesecke, E. P., General Elec. Co., Philadelphia, Pa.
Gifford, D. R., Pennsylvania State College, State College, Pa.
Goetz, J. E., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Gohlke, C. H., N.A.C.A., Cleveland, Ohio
Goldsberry, P. E., I.B.M. Co., Columbus, Ohio
Gonder, C. R., Hall Radio Labs., Pittsburgh, Pa.
Gordon, W. H., Jr., Pennsylvania State College, State College, Pa.
Grant, L. A., Toledo Edison Co., Toledo, Ohio
Gribble, W. G., Sharon Steel Corp., Sharon, Pa.
Gruber, W. M., Brown Instrument Co., Philadelphia, Pa.
Grumblatt, J. J., Pennsylvania Tel. Corp., Erie, Pa.
Gunnels, W. F., Jr., General Elec. Co., Philadelphia, Pa.
Haas, N. V., Raymond Rosen Engg. Products, Inc., Philadelphia, Pa.
Hall, R. L., The Lincoln Elec. Co., Pittsburgh, Pa.
Hanusi, J. P., Jr., Eastern Gas & Fuel Assocs., Beards Fork, W. Va.
Happel, W. J., Gulf Research & Development Co., Pittsburgh, Pa.
Harnish, H. G., Brown Instrument Co., Philadelphia, Pa.
Hart, C. J., Toledo Edison Co., Toledo, Ohio
Hattrup, G. J., Westinghouse Elec. Corp., Sharon, Pa.
Heh, R. J., Duquesne Light Co., Pittsburgh, Pa.
Heidenreich, G. E., Jr., The Cincinnati Gas & Elec. Co., Cincinnati, Ohio
Hein, D. C., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Heinrich, R. A., Edwin L. Wiegand Co., Pittsburgh, Pa.
Hendricks, J. B., Pennsylvania Railroad Co., Philadelphia, Pa.
Hermanson, C. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Herold, C. P., Consolidated Gas Elec. Light & Power Co. of Baltimore, Baltimore, Md.
Herrman, B. W., Champion Paper & Fibre Co., Hamilton, Ohio
Hewett, E. B., General Elec. Co., Philadelphia, Pa.
Hines, F. E., Joseph S. Finch & Co., Schenley, Pa.
Hippe, G. A., Carbide & Carbon Chem. Corp., S. Charleston, W. Va.
Hobson, J. F., United Engrs. & Constructors, Inc., Philadelphia, Pa.
Hofacker, R. E., Ohio Edison Co., Akron, Ohio
Holmer, I. G., Dayton Power & Light Co., Dayton, Ohio
Honan, H. D., Jr., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Horowitz, N., Rural Electrification Admin., Washington, D. C.
Huber, J. G., RCA Service Co., Inc., Gloucester, N. J.
Hugon, B. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Hummel, C. F., Kellex Corp., Silver Spring, Md.
Imblum, H. J., Republic Steel Corp., Niles, Ohio
Jacob, F., Glenn L. Martin Co., Middle River, Md.
Jackson, J. F., Robbins & Myers, Springfield, Ohio
Johannesmeyer, E. W., Talon, Inc., Meadville, Pa.
Johnson, E. L., Jr., Bendix Corp., Towson, Md.
Johnson, R. H., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Johnston, H. L., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Jones, F. M. (re-election), General Elec. Co., Philadelphia, Pa.
Jones, L. C., Natl. Elec. Coil Co., Columbus, Ohio
Kaczor, W. J., United Engrs. & Constructors Inc., Philadelphia, Pa.
Kappeler, C. P., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Karnes, K. A., Republic Steel Corp., Warren, Ohio
Kasum, E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Kaul, H. J., Westinghouse Elec. Corp., Wilkinsburg, Pa.
Keller, D. C., Toledo Edison Co., Toledo, Ohio
Kerber, W., Jr., General Elec. Co., Philadelphia, Pa.
Ketchum, J. R., N.A.C.A., Cleveland, Ohio
Kidston, F. G., Millville Mfg. Co., Millville, N. J.
King, D. C., Dayton Power & Light, Dayton, Ohio
Kirkland, R. W., Jr., General Elec. Co., Baltimore, Md.
Kister, N. M., Gilbert Assocs., Inc., Reading, Pa.
Kleckner, C. C., American Tel. & Tel., Allentown, Pa.
Klingaman, G. W., Radio Corp. of America, Camden, N. J.
Knox, W., Reliance Elec. & Engg. Co., Cleveland, Ohio
Knudson, B. C., Rural Electrification Admin., Washington, D. C.
Koenig, J. G., Timken Roller Bearing Co., Canton, Ohio
Konevich, G. R., Westinghouse Elec. Co., E. Pittsburgh, Pa.

Koppel, H. H., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Kozloski, T. E., Carnegie-Illinois Steel Corp., Dravosburgh, Pa.
Kristof, J. A., Cincinnati Gas & Elec. Co., Cincinnati, Ohio
Kuhn, J. G., I.B.M. Corp., Pittsburgh, Pa.
Kunes, J. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Kuney, J. S., Pennsylvania Power & Light Co., Allentown, Pa.
Largen, W. M., Youngstown Sheet & Tube Co., Youngstown, Ohio
Leone, H. A., Westinghouse Elec. Corp., Pittsburgh, Pa.
Levin, M. S., Electro Construction Co., Philadelphia, Pa.
L'Heureux, L. J. J., Johns Hopkins Univ., Baltimore, Md.
Levinson, S., Natl. Bureau of Standards, Washington, D. C.
Licini, F. R., Pennsylvania Power & Light Co., Allentown, Pa.
Limanek, S. J., Catholic Univ., Washington, D. C.
Lindsey, J. T., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Little, J. C., American Steel & Wire Co., Cleveland, Ohio
Long, P. H., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Long, W. E., United Engrs. & Constructors, Inc., Philadelphia, Pa.
Lovelace, C. E., Guyan Machinery Co., Logan, W. Va.
Luff, F. T., R.E.A., Washington, D. C.
Lukacs, N., Imperial Coal Corp., Johnstown, Pa.
Lundin, J. A., Westinghouse Elec. Corp., Pittsburgh, Pa.
Lyman, R., Goodyear Aircraft Corp., Akron, Ohio
Lynch, B. J., Duquesne Light Co., Pittsburgh, Pa.
Lyons, L. H., General Industries, Inc., Philadelphia, Pa.
Maher, J. I., Harlan Elec. Const. Co., Toledo, Ohio
Maley, T. F., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Manecke, S. E., Westinghouse Elec. Corp., Mansfield, Ohio
Mann, D. K., Duquesne Light Co., Pittsburgh, Pa.
Manni, J. B., Allis Chalmers Mfg. Co., Pittsburgh, Pa.
Manni, V. E., Allis Chalmers Mfg. Co., Pittsburgh, Pa.
Marcks, D. F., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Markle, J. E., Ohio Public Service Co., Cleveland, Ohio
Marston, A. D., Potomac Elec. Power Co., Washington, D. C.
Maruchi, W. L., Philadelphia Elec. Co., Philadelphia, Pa.
Massey, D. E., Stockwell Transformer Corp., Akron, Ohio
Massey, T., Jr., Bethlehem Steel Co., Sparrows Point, Md.
Matteucci, L. J., Blaw-Knox Constr. Co., Pittsburgh, Pa.
Mayall, G. W., Pennsylvania Transformer Co., Pittsburgh, Pa.
McCann, R. P., 150 Cooper Ave., Johnstown, Pa.
McComas, A. D., Jr., Bendix Radio Div., Towson, Md.
McConnell, W. L., Bell Tel. Co. of Pa., Pittsburgh, Pa.
McCrary, M. R., National Carbon Co., Cleveland, Ohio
McDonald, T. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
McKean, A. H., Jr., Allegheny Industrial Elec. Co., Pittsburgh, Pa.
McMillan, H. A., General Elec. Co., Youngstown, Ohio
McNerney, A. T., Chesapeake & Potomac Tel. Co., Washington, D. C.
McWhinney, R. C., Pittsburgh Railways Co., Pittsburgh, Pa.
Mengle, L. I., The Bell Tel. Co. of Pennsylvania, Harrisburg, Pa.
Mercker, A. J., Reliance Elec. & Engg. Co., Cleveland, Ohio
Merrill, E. F., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Merris, C. E., (re-election), General Elec. Co., Philadelphia, Pa.
Mertzluefft, D. J., Graybar Elec. Co., Cleveland, Ohio
Miller, A. N., Philco Corp., Philadelphia, Pa.
Miller, H. R., Armco Steel Corp., Butler, Pa.
Miller, J. F., Jr., Duquesne Light Co., Pittsburgh, Pa.
Miller, J. H., Glenn L. Martin Co., Baltimore, Md.
Miller, J. W., Pennsylvania State College, State College, Pa.
Miller, R. E., Johns Hopkins Univ., Silver Spring, Md.
Momoda, M. M., Westinghouse Elec. Corp., Sharon, Pa.
Monito, G. A., Westinghouse Elec. Corp., Sharon, Pa.
Montgomery, J. N., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Moon, C. G., General Elec. Co., Erie, Pa.
Moore, R. W., Petroleum Rectifying Co., Toledo, Ohio
Moore, S. F., Sylvania Elec. Products, Inc., Huntington, W. Va.
Morgan, W. T., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Mullen, J. H., Rural Electrification Admin., Washington, D. C.
Muschlitz, W. L., Pennsylvania State College, State College, Pa.
Naugle, P. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Naylor, A. F., Radio Corp. of America, Camden, N. J.
Neilly, V. E., The Pennsylvania State College, State College, Pa.
Nelson, P. H., Public Service Elec. & Gas Co., Camden, N. J.
New, W. C., General Elec. Co., Philadelphia, Pa.
Nikel, F. R., Line Material Co., Zanesville, Ohio
Nonemaker, L. L., Pennsylvania Power & Light Co., Allentown, Pa.
Norton, J. R., Metropolitan Edison Co., Lebanon, Pa.
Novotny, J. J., Chesapeake & Potomac Tel. Co. of Baltimore City, Baltimore, Md.
O'Brien, L. T., Westvaco Chemical Co., South Charleston, W. Va.
Ocker, A. C., Bell Tel. Co. of Pennsylvania, Pittsburgh, Pa.
Omler, J. R., Box 345, Route 1, Maumee, Ohio
Ott, R. C., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Outen, R. L., Potomac Edison Co., Frederick, Md.
Owoc, V. A., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Paris, C. H., U. S. Coal & Coke Co., Gary, W. Va.
Parisi, J. H., Reliance Elec. & Engg. Co., Cleveland, Ohio
Parks, W. W., National Tube Co., Lorain, Ohio
Pastel, M. P., RCA Victor, Camden, N. J.
Pearson, A. H., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Peelman, R. K., General Elec. Co., Erie, Pa.
Perch, D. F., Elec. Auto-Lite, Toledo, Ohio
Perry, B. A., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Perry, R. H., Lehigh Portland Cement Co., Allentown, Pa.
Peterson, R. F., REA, Washington, D. C.
Phelps, G. V., General Elec. Co., Philadelphia, Pa.
Pickett, L. A., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Pierce, E. W., Packard Motor Car Co., Toledo, Ohio
Polk, C., R.C.A., Camden, N. J.
Porch, C. C., Associated Factory Mutual Fire Ins. Cos., Philadelphia, Pa.
Porter, J. R., Crosley Broadcasting Co., Cincinnati, Ohio
Pressel, P. I., Ohio State Univ., Columbus, Ohio
Pughe, E. W., Jr., General Elec. Co., Tiffin, Ohio
Quinn, L. P., Glenn L. Martin Co., Baltimore, Md.
Quisenberry, D. T., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Rabek, E. E., Reliance Elec. & Engg. Co., Cleveland, Ohio
Ramsey, A. R., General Elec. Co., Erie, Pa.
Redick, R. E., Ohio Inspection Bureau, Lima, Ohio
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Reynolds, G. C., United Engrs. & Constructors, Inc., Philadelphia, Pa.
Ricker, R. M., Taylor-Winfield Corp., Warren, Ohio
Riggs, R. N., Glenn L. Martin Co., Baltimore, Md.
Ripnitz, A., Natl. Bureau of Standards, Washington, D. C.
Roadarmel, H. W., Jr., Bell Tel. Co. of Pa., Harrisburg, Pa.
Rolston, F., III, Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Roseman, H. M., Philadelphia Navy Yard, Philadelphia, Pa.
Ross, J. L., Pennsylvania Power & Light Co., Allentown, Pa.
Ross, J. M., Crosley Div., Avco Mfg. Corp., Cincinnati, Ohio
Rothar, D. E., Baltimore Signal Depot, Middle River, Md.
Ruszkiewicz, J. E., U. S. Patent Office, Washington, D. C.
Sachs, H., General Industries Inc., Philadelphia, Pa.
Sand, E. C., Reliance Elec. Cleveland, Ohio
Sandy, G. F., Jr., Packard Elec. Div., G.M.C., Warren, Ohio
Schaibley, J. R., Westinghouse Elec. Corp., Pittsburgh, Pa.
Schmidt, E. C., Reliance Elec. & Engg. Co., Cleveland, Ohio
Schmitt, J. E., Rural Electrification Admin., Washington, D. C.
Schroeder, P. L., Duquesne Light Co., Pittsburgh, Pa.
Schultz, A. J., General Elec. Co., Philadelphia, Pa.
Scoville, J. F., General Elec. Co., Erie, Pa.
Seibert, D. J., General Elec. Co., Philadelphia, Pa.
Senitzky, B., Flight Propulsion Lab., Cleveland Airport, Cleveland, Ohio
Shea, E. T., Univ. of Pennsylvania, Philadelphia, Pa.
Shepard, E. O., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Sidnell, N. A., General Elec. Co., Philadelphia, Pa.
Siebers, R. W., General Elec. Co., Erie, Pa.
Silliman, S. D., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Silver, M., Naval Air Material Center, Philadelphia, Pa.
Simmons, A. J., Philadelphia Elec. Co., Philadelphia, Pa.
Simmons, R. W., West Penn Power Co., Pittsburgh, Pa.
Simon, M., General Elec. Co., Erie, Pa.
Sinsel, P. W., The Chesapeake & Potomac Tel. Co. of W. Va., Charleston, W. Va.
Slavin, M., Bendix Radio Co., Towson, Md.
Slebodnik, T. W., Westinghouse Elec. Corp., Beaver, Pa.
Slingluff, P. E., Republic Steel Corp., Massillon, Ohio
Smith, F. A., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Smith, G. A., Duquesne Light Co., Pittsburgh, Pa.
Smith, H. C., Westinghouse Elec. Corp., Cleveland, Ohio
Spanos, G., Pennsylvania State College, State College, Pa.
Stawarski, C. C., J & L Steel Corp., Pittsburgh, Pa.
Steelman, J., Jr., International Nickel Co., Inc., Huntington, W. Va.
Steiner, J. R., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Stewart, A. C., Cincinnati Gas & Elec. Co., Cincinnati, Ohio
Stewart, C. R., Railway & Industrial Engg. Co., Greensburg, Pa.
Stevenson, J. F., Brown Instrument Div. Minn.-Honeywell Reg. Co., Philadelphia, Pa.
Stickney, T. M., N.A.C.A., Cleveland Airport, Cleveland, Ohio
Stone, H. H., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Stonesifer, R. A., Elliott Co., Inc., Ridgway, Pa.
Stuckeman, W. H., W. F. Stuckeman & Co., Pittsburgh, Pa.
Sumner, C. O., Jr., Consolidated Gas, Elec. Light & Power Co. of Baltimore, Baltimore, Md.
Swanson, R. D., The Cincinnati Gas & Elec. Co., Cincinnati, Ohio
Swanson, R. D., Rural Electrification Admin., Washington, D. C.
Takes, D. E., Curtiss-Wright Corp., Columbus, Ohio
Tass, M. H., Goodyear Aircraft Corp., Akron, Ohio
Taylor, A., General Elec. Service Shop, Cincinnati, Ohio
Terwilliger, H. G., Ohio Edison Co., Akron, Ohio
Thomas, J. B., Koppers Co. Inc., Baltimore, Md.
Thomasson, H. B., Natl. Broadcasting Co., Inc., Washington, D. C.
Thompson, D. B., The Glenn L. Martin Co., Baltimore, Md.
Throop, G. D., Westinghouse Elec. Corp., Sharon, Pa.
Tiede, R. V., Johns Hopkins Univ., Baltimore, Md.
Toth, M., Jr., Elliott Co., Jeannette, Pa.
Tracy, T. J. R., Goodyear Aircraft Corp., Akron, Ohio
Tsevdos, T. J., RCA Victor, Camden, N. J.
Tyler, H. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
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Verner, D. R., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Veres, J., Elliott Co., Ridgway, Pa.
Volker, G. V., Mesta Machine Co., W. Homestead, Pa.
Wagner, C. S., American Tel. & Tel. Co., Cleveland, Ohio
Wagner, M. J., Wolfe & Mann Mfg. Co., Baltimore, Md.
Wall, J. C., Enslow Machinery Co., Huntington, W. Va.
Waltz, W. C., Dayton Power & Light Co., Dayton, Ohio
Wantland, P. F., General Elec. Co., Erie, Pa.
Watson, T. F., Jr., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Weintraub, I., Tinius Olsen Testing Machine Co., Willow Grove, Pa.
Weischedel, R. C., General Elec. Co., Philadelphia, Pa.
Werner, J. F., Toledo Edison Co., Toledo, Ohio
Wessel, R. F. H., Dayton Power & Light Co., Dayton, Ohio
Weyrick, R. C., Goodyear Tire & Rubber Co., Akron, Ohio
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Wick, L. L., Rural Electrification Admin., Washington, D. C.
Wilburn, G. C., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Wilk, J. F., Pennsylvania Tel. Co., Erie, Pa.
Williams, F. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Woodside, G. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Wrasse, H. V., General Cable Corp., Philadelphia, Pa.
Wrenn, W. E., Westinghouse Elec. Corp., Sharon, Pa.
Wuerth, R. C., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Wylde, D. V., General Elec. Co., Philadelphia, Pa.
Yarbrough, J. M., The Mead Corp., Chillicothe, Ohio
Yunker, R. W., Pittsburgh Plate Glass, Creighton, Pa.
Zwart, C., Westinghouse Elec. Corp., Philadelphia, Pa.

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Acker, J. G., Long Island Lighting Co., Mineola, N. Y.
Albin, F. I., Lancashire Imports Ltd., New York, N. Y.
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Anfanger, R. A., Thermodyne Corp., New York, N. Y.
Axelrod, J., Gibbs & Hill, New York, N. Y.
Baird, D. R., Federal Tel. & Radio Corp., Clifton, N. J.
Balogh, J., Singer, Ehlert, Stern & Carlberg, New York, N. Y.
Barton, G. R., Ford Instrument Co., Long Island City, N. Y.
Beardsworth, R., Sperry Gyroscope Co., Great Neck, N. Y.
Beaulieu, C. E., Ebasco Services, Inc., New York, N. Y.
Beckman, F. W., Consolidated Edison Co., New York, N. Y.
Bello, L. A., Syska & Hennessy, New York, N. Y.
Bentowsky, J., Sperry Gyroscope Co., Great Neck, N. Y.
Bernstein, R. I., Tube Light Engg. Co., New York, N. Y.
Boice, A. F., U. S. Army, Ft. Monmouth, Red Bank, N. J.
Boyajian, J., Ford Instrument Co., Long Island City, N. Y.
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Broderick, W. C., Voorhees, Walker Foley & Smith, New York, N. Y.
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Callan, H., Kearfott Co., Inc., New York, N. Y.
Carroll, W. J., Arma Corp., Brooklyn, N. Y.
Carson, W. R., Trenton Junior College, Trenton, N. J.
Chamos, A. W., The Texas Co., New York, N. Y.
Chomsky, S. R., Natl. Broadcasting Co., New York, N. Y.
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Cooper, B. L., Sperry Gyroscope Co., Great Neck, N. Y.
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DeVincent, J., Avion Instrument Corp., New York, N. Y.
Dobrofsky, A., The Okonite Co., Passaic, N. J.
Doerfel, H. V., Naval Air Development Sta., Hammonton, N. J.
Dugandzic, P. F., M. W. Kellogg Co., Jersey City, N. J.
Dusenberry, R. F., Bell Tel. Lab. Inc., New York, N. Y.
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Emmel, L. L., Tung-Sol Lamp Works, Bloomfield, N. J.
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Kennedy, P. C., American Transformer Co., Newark, N. J.
Klein, G. F., N.Y.C. Board of Transportation, New York, N. Y.
Klein, R. J., Serval Slide Fasteners, Inc., Flushing, N. Y.
Kooperstein, R., Bureau of Bridge Design, New York, N. Y.
Koval, E. A., Western Union Tel. Co., New York, N. Y.
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Martone, J. I., Long Island Lighting Co., Mineola, L. I., N. Y.
McDuffie, G. L., Westinghouse Intl. Co., New York, N. Y.
McTague, P. J., Long Island Lighting System, Mineola, N. Y.
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Meister, J., Picatinny Arsenal, Dover, N. J.
Menes, M., C.C.N.Y., New York, N. Y.
Mercer, D. W., Ebasco Services, Inc., New York, N. Y.
Metsky, D., Dura Elec. Lamp Co., Inc., Newark, N. J.
Miller, R. M., Westinghouse Elec. & Intl. Co., New York, N. Y.
Minogue, J. P., Telautograph Corp., New York, N. Y.
Mintzer, G., Hamel—Gaynor Assocs., New York, N. Y.
Mitwol, S., Bart-Messing Corp., Brooklyn, N. Y.
Morrison, J. A., Westinghouse Elec. Int'l. Co., New York, N. Y.
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Nellis, R. E., Chase Aircraft Co., Inc., W. Trenton, N. J.
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O'Brien, D. J., Murray Mfg. Corp., Brooklyn, N. Y.
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Pace, R. T., Sylvania Elec. Products, Inc., Bayside, N. Y.
Pantchechnikoff, J. I., R.C.A. Labs., Princeton, N. J.
Paschetto, D. D., Federal Tel. & Radio Co., Nutley, N. J.
Peterson, E. W., The Commonwealth & Southern Corp., New York, N. Y.
Piper, R. B., Copperweld Steel Int'l. Co., New York, N. Y.
Pollak, F., C.C.N.Y., New York, N. Y.
Portnoy, A., Western Union Tel. Co., New York, N. Y.
Pritkin, L., Eastern Air Devices, Brooklyn, N. Y.
Putallaz, F. J., American Tel. & Tel. Co., New York, N. Y.
Quick, H. K., Bell Tel. Labs., Inc., New York, N. Y.
Rappuhn, H. W., Westinghouse Elec. Corp., Jersey City, N. J.
Rea, W. W., Hazeltine Electronics Corp., Little Neck, N. Y.
Reddy, R. F., Caldwell & Scott, Inc., New York, N. Y.
Revzinsa, S. A., Camp Coles Sig. Corps Engg. Lab., Red Bank, N. J.
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Ryan, W. A., Ebasco Services, Inc., New York, N. Y.
St. Onge, G. H., Standard Oil Development Co., Elizabeth, N. J.
Salazar, R. E., Corporacion de Fomento, New York, N. Y.
Samson, R. L., Western Union Tel. Co., New York, N. Y.
Saunders, J. H., Jr., Anaconda Wire & Cable Co., Hastings-on-Hudson, N. Y.
Scharfman, H., Brooklyn Polytech. Inst., Brooklyn, N. Y.
Scheuer, L. J., Ford Instrument Co., Long Island City, N. Y.
Schiffenbauer, M., Arma Corp., Brooklyn, N. Y.
Schlossberg, H., Fischbach & Moore, Inc., New York, N. Y.
Schneyer, A. T., Bendix Aviation Corp., Eclipse Pioneer Div., Teterboro, N. J.
Schroeder, G. F., Ford Instrument Co., Long Island City, N. Y.
Schustack, W. L., Devenco Inc., New York, N. Y.
Serafin, J., American Broadcasting Co., New York, N. Y.
Shustrin, R., Board of Transportation City of N. Y., New York, N. Y.
Siegel, G. H., Remington Rand, Inc., New York, N. Y.
Silverman, E., Long Island Lighting Co., Mineola, N. Y.
Simon, S. J., General Instrument Co., Inc., Elizabeth, N. J.
Sittig, E. A., Ward Leonard Elec. Co., Mt. Vernon, N. Y.
Slade, B. N., RCA Victor Div., Harrison, N. J.
Smithline, H., Sylvania Elec. Products, Inc., Flushing, N. Y.
Spergel, P., Sperry Gyroscope Co., Great Neck, N. Y.
Spillane, J., Westinghouse Elec. Corp., New York, N. Y.
Stanley, J. K., Anaconda Wire & Cable Co., Hastings-on-Hudson, N. Y.
Stenquist, R. C., The Kellex Corp., New York, N. Y.
Sternberg, J. R., Remington-Rand, New York, N. Y.
Stoliar, A. P., Arma Corp., Brooklyn, N. Y.
Strauss, R., Hydropress, Inc., New York, N. Y.
Strohm, W. B., Devenco Inc., New York, N. Y.
Strom, L. D., Hazeltine Electronics Corp., Little Neck, L. I., N. Y.
Tahan, E., Air Assoc., Inc., Teterboro, N. J.
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Unger, M. I., N. J. Power & Light Co., Dover, N. J.
Verven, S. J., I.B.M. Corp., Poughkeepsie, N. Y.
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Waldman, R. A., General Elec. Supply Corp., New York, N. Y.
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4. SOUTHERN

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Bentley, C. A., American Air Filter, Louisville, Ky.
Berly, R. H., Jr., Carolina Power & Light Co., Marion, S. C.
Berry, J. J., South East-Joslyn Co., Birmingham, Ala.
Blake, B. S., Jr., Western Union Tel. Co., Atlanta, Ga.
Boenning, W. R, Engg. Research Assocs., Inc., Arlington, Va.
Borges, M. F, Southern Bell Tel. & Tel. Co., New Orleans, La.
Bowen, L. O., Jr., United Gas Pipe Line Co., Shreveport, La.
Britnell, W. F., T.V.A., Wilson Dam, Ala.
Burgin, S., Carolina Power & Light Co., Asheville, N. C.
Burkhead, C. I., Jr., Public Works Comm., Fayetteville N. C.
Cannon, H. T., Jr., General Elec. Co., Owensboro, Ky.
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Chandler, F. W., T.V.A., Chattanooga, Tenn.
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Estep, C. S., Mathieson Chem. Corp., Saltville, Va.
Evans, E. O., Mutual Boiler Ins. Co. of Boston, Spartanburg, S. C.
Evans, J. W., Jr., The Citadel, Charleston, S. C.
Farley, P. T., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
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Fisher, T. C., E. I. DuPont de Nemours & Co., Old Hickory, Tenn.
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Gilreath, J. A., Schlumberger Well Surveying Corp., New Iberia, La.
Gimber, J. P., Southern Advance Bag & Paper Co., Hodge, La.
Goodman, W. E., Line Material Co., Memphis, Tenn.
Gunby, W. H., Schlumberger Well Surveying Corp., Houma, La.
Harrison, R. E., American Lava Corp., Chattanooga, Tenn.
Henderson, O. O., Ky. & W. Va. Power Co., Ashland, Ky.
Herring, O. W., The Okonite Co., Birmingham, Ala.
Hull, H. H., Florida Power & Light Co., Sarasota, Fla.
Hunt, E. B., South Dakota School of Mines, Rapid City, S. Dak.
Hurstell, M. L., New Orleans Public Service, Inc., New Orleans, La.
Jackson, R. G., Virginia Elec. & Power Co., Norfolk, Va.
Kirk, K. D., Kentucky Utilities Co., Pineville, Ky.
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Land, J. E., Southern Bell Tel. & Tel. Co., Columbia, S. C.
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Rupard, P., Princess Elkhorn Coal Co., Prestonburg, Ky.
Shriner, V. A., Jr., Va. Elec. & Power Co., Alexandria, Va.
Skaggs, G. W., Jr., Appalachian Elec. Power Co., Roanoke, Va.
Slaughter, G. G., Duke Univ., Durham, N. C.
Smith, J. A., Aluminum Co. of America, Alcoa, Tenn.
Smith, L. M., Westinghouse Elec. Corp., Charlotte, N. C.
Somerville, J. R., Jr., General Elec. Co., Owensboro, Ky.
Spiegel, G., 3924 Kimpalong Rd., Nashville, Tenn.
Stewart, R. E., Schlumberger Well Surveying Corp., Natchez, Miss.
Stouse, P. J., Jr., New Orleans Public Service Inc., New Orleans, La.
Strausser, E. A., Patterson & Dewar Engrs., Decatur, Ga.
Summers, C. R., N.A.C.A., Langley Field, Hampton, Va.
Taft, C. H., I.B.M. Co., Chattanooga, Tenn.
Tammany, F. C., E. I. du Pont Co., Richmond, Va.
Thomas, D. L., Southern States Equipment Corp., Birmingham, Ala.
Thomas, W. N., Virginia Elec. & Power Co., Norfolk, Va.
Thompson, L. H., I.B.M. Corp., Winston-Salem, N. C.
Tipton, D. C., Jr., T.V.A., Chattanooga, Tenn.

Valdez, C., Stone & Webster Engr. Corp., Baton Rouge, La.
Veigl, G., Avondale Mills, Sylacauga, Ala.
Warren, F. J., Jr., Gulf States Utilities Co., Baton Rouge, La.
Wells, G. F., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
White, R. W., Lockhart Power Co., Lockhart, S. C.
Wilcox, R. L., Carter Oil Co., Many, La.
Williams, J., General Elec. Supply Corp., Memphis, Tenn.
Williamson, D. R., Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Wilson, E. K., Jr., Alabama Power Co., Oneonta, Ala.
Wilson, D. R., Stone & Webster Engr. Corp., Baton Rouge, La.
Wilson, H. C., Jr., Mississippi Power & Light Co., Jackson, Miss.
Windham, W. L., Jr., Alabama Power Co., Birmingham, Ala.
Wiseman, R. S., Mississippi State College, State College, Miss.
Zumwalt, W. T., T.V.A., Knoxville, Tenn.

5. Great Lakes

Abrams, J. L., Stone & Webster Engg. Corp., Prospect, Ill.
Anderhous, B., Elgin, Joliet & Eastern Rwy. Co., Joliet, Ill.
Armbruster, T. F., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Atran, L., Hub Elec. Co., Chicago, Ill.
Avery, B. F., General Elec. Co., Detroit, Mich.
Avery, J. P., Western Elec. Co., Speedway City, Ind.
Bahti, J. H., Univ. of Mich., Ann Arbor, Mich.
Baker, O. N., Milwaukee Fire & Police Alarm Div., Milwaukee, Wis.
Banner, D. W., Square D Co., Detroit, Mich.
Baxter, A. L., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Beardsley, L. R., Illinois Inst. of Tech., Chicago, Ill.
Bembenick, C. W., General Motors Corp., La Grange, Ill.
Benike, H. R., Pyle-National Co., St. Paul, Minn.
Berglund, A. Q., Route 3, Box 66, Evansville, Minn.
Bern, H. R., Iowa Elec. Light & Power Co., Marshalltown, Iowa
Berry, R. L., Iowa Southern Utilities Co., Centerville, Iowa
Blaisdell, G. L., 850 Baker St., Wisconsin Rapids, Wis.
Blank, H. F., Louis Allis Co., Milwaukee, Wis.
Bodin, N. A., Iowa-Illinois Gas & Elec. Co., Rock Island, Ill.
Bond, H. E., Underwriters' Lab. Inc., Chicago, Ill.
Bonneau, U. J., Socony Vacuum Oil Co., E. Chicago, Ill.
Bouton, J. C., Globe-Union, Inc., Milwaukee, Wis.
Boyle, C. F., Sparks-Withington Co., Jackson, Mich.
Brackett, R. C., Univ. of Chicago, Chicago, Ill.
Brazas, V. J., Commonwealth Edison Co., Chicago, Ill.
Briggs, R. H., Bendix Aviation Corp., South Bend, Ind.
Brogdon, H. F., Borg-Warner Corp., Herrin, Ill.
Bronikowski, R. J., Curtis Dev. & Mfg. Co., Milwaukee, Wis.
Buerosse, A. D., Marathon Elec. Mfg. Corp., Wausau, Wis.
Burdett, R. D., General Elec. Co., Ft. Wayne, Ind.
Butterfield, D. C., Consumers Power Co., Manistee, Mich.
Caloyeros, I., Armour Research Foundation, Chicago, Ill.
Campbell, C. E., (re-election), General Elec. Co., Detroit, Mich.
Campbell, D. D., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Caple, V. R., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Carey, W. A., Public Service of No. Illinois, Joliet, Ill.
Carl, D. C., Iowa Public Service Co., Storm Lake, Iowa
Caveney, J. E., Commonwealth Edison Co., Chicago, Ill.
Chalupnik, A. N., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Colman, S. T., Square D Co., Detroit, Mich.
Conway, P. W., Rauland Corp., Chicago, Ill.
Christensen, C. L., Iowa Public Serv. Co., Sioux City, Iowa
Chu, T-S, Northwestern Univ., Evanston, Ill.
Chubbuck, S. O., Abrams Instrument Corp., Lansing, Mich.
Church, R. L., Wisconsin Elec. Power Co., Milwaukee, Wis.
Cohn, M., Hub Elec. Co., Chicago, Ill.
Collins, E. L., Allis-Chalmers Mfg. Co., West Allis, Wis.
Cook, G. A., Iowa Elec. Light & Power Co., Cedar Rapids, Iowa
Corajod, K. H., Illinois Central Railroad, Chicago, Ill.
Coulson, R. E., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Crossley, C. N., Redmond Co., Inc., Owosso, Mich.
Cook, W. O., P. R. Mallory Co., Inc., Indianapolis, Ind.
Dennis, R. L., Ford Motor Co., Dearborn, Mich.
De Sieno, C. F., Commonwealth Edison Co., Chicago, Ill.
Donelan, L. E., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Dreffin, R. S., Public Service Co. of Northern Illinois, Maywood, Ill.
Dripps, W. F., General Elec. Co., Ft. Wayne, Ind.
Duncan, R. O., Iowa-Illinois Gas & Elec. Co., Rock Island, Ill.
Edstrom, C. A., Radio Sta. KSTP, Inc., St. Paul, Minn.
Elabd, I. H. A., Univ. of Mich., Ann Arbor, Mich.
Ellison, G. P., Ellerbe & Co., St. Paul, Minn.
Elwonger, E. D., General Elec. Co., Ft. Wayne, Ind.
Engstrom, D. F., Cutler-Hammer Inc., Milwaukee, Wis.
Erdmann, R. G., General Elec. Co., Ft. Wayne, Ind.
Fagen, L. G., Westinghouse Elec. Corp., Chicago, Ill.
Faulds, D. W., Rochester City Light Plant, Rochester, Minn.
Fensholt, E. C., Commonwealth Edison Co., Chicago, Ill.
Ferguson, E. R., General Elec. Co., Ft. Wayne, Ind.
Fessenden, K. P., Fairbanks, Morse & Co., Beloit, Wis.
Flory, G. C., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Flota, D., Sahara Coal Co., Harrisburg, Ill.
Frazer, W. B., Chrysler Corp., Detroit, Mich.
French, R. X., Jr., Sargent & Lundy, Chicago, Ill.
Fricke, R. A., Ladish Co., Cudahy, Wis.
Friddle, R. M., Allis Chalmers Mfg. Co., Milwaukee, Wis.
Fruehauf, F. E., Detroit Edison Co., Detroit, Mich.
Gauthier, W. D., Chrysler Corp., Detroit, Mich.
Geers, G. J., Monsanto Chemical Co., Monsanto, Ill.
Gemlo, J. E., Square D Co., Milwaukee, Wis.
Giannini, J. F., Pullman-Standard Car Mfg. Co., Hammond, Ind.
Godoshian, A., Detroit Edison Co., Detroit, Mich.
Goettel, H. J., American Tel. & Tel. Co., Watseka, Ill.
Goldsmith, P., Armour Research Foundation, Chicago, Ill.
Goodier, G. N., Pennsylvania Railroad, Terre Haute, Ind.
Gottsacker, R. F., Square D Co., Milwaukee, Wis.
Gourley, W. L., (Student), Purdue Univ., W. Lafayette, Ind.
Graebner, M. S. J., Gausman & Moore, St. Paul, Minn.
Grand-Girard, S., Jr., Consumers Power Co., Jackson, Mich.
Gratny, P. S., General Elec. Co., Ft. Wayne, Ind.
Gyger, C. E., Allis Chalmers Mfg. Co., Milwaukee, Wis.
Gyure, W. A., Greeley & Hansen, Chicago, Ill.
Hageman, L. C., Public Service Co. of Northern Illinois, Maywood, Ill.
Hamer, A. K., Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Hansen, C. W., General Elec. X-Ray Corp., Milwaukee, Wis.
Harris, M., Coyne Electrical School, Chicago, Ill.
Henry, W. R., Shell Oil Co., Woodriver, Ill.
Hetlinger, F. J., (Student), Univ. of Minnesota, Minneapolis, Minn.
Hoefer, W. G., General Elec. Co., Ft. Wayne, Ind.
Hoffman, H. E., Wheelco Instruments Co., Chicago, Ill.
Horney, J. C., Jr., Sangamo Elec. Co., Springfield, Ill.
Horton, E. J., Commonwealth Edison Co., Chicago, Ill.
Howard, F. S., II, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Hudson, C. H., Jr., General Elec. Co., Ft. Wayne, Ind.
Hunter, R. B., The Detroit Edison Co., Detroit, Mich.
Jenkins, J. J., Jr., Produce Terminal Corp., Chicago, Il.
Joerger, J. C., Univ. of Wisconsin, Madison, Wis.
Kanjorski, R. L., A. O. Smith Corp., Milwaukee, Wis.
Kaplan H., Precision Transformer Co., Chicago, Ill.
Kasper, D. G., Barber-Colman Co., Rockford, Ill.
Kavon, M. J., Globe Union Inc., Milwaukee, Wis.
Kawiecki, C. J., Commonwealth Edison Co., Chicago, Ill.
Kempf, K. R., Univ. of Notre Dame, Notre Dame, Ind.
Kersey, A. F., Cutler-Hammer Inc., Milwaukee, Wis.
King, J. M., R. R. #6 Paris, Ill.
Kingsland, R. L., Jr., Elliott Co., Chicago, Ill.
Kirke, J. H., City Light & Power Works, Ft. Wayne, Ind.
Kissinger, W. H., General Elec. X-Ray Corp., Milwaukee, Wis.
Klapper, D. B., Public Service Co. of Northern Ill., Chicago, Ill.
Kmet, A., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Knowles, R. G., Barber-Colman Co., Rockford, Ill.
Kroker, R. G., Nader Engr. Co., Chicago, Ill.
Kulzick, R. F., Wisconsin Elec. Power Co., Milwaukee, Wis.
Kurland, J. A., Commonwealth Edison Co., Chicago, Ill.
Langenhorst, R. D., Detroit Edison Co., Detroit, Mich.
Laubenstein, D. F., Commonwealth & Southern Corp., Jackson, Mich.
Laughlin, J. T., J. Livingston & Co., Chicago, Ill.
Lee, R. E., Northern States Power Co., Minneapolis, Minn.
Lesgold, R. B., Herlec Corp., Milwaukee, Wis.
Liebow, W., 6818N Wayne Ave., Chicago, Ill.
Linder, L. E., Ulteig Engg. Corp., Fargo, N. Dak.
Lipkin, L., Wayne Univ., Detroit, Mich.
Longley, D. D., Electro-Motive Div., G.M.C., LaGrange, Ill.
MacLeod, D. D., Michigan Bell Tel. Co., Detroit, Mich.
Martin, D. C., Fairbanks Morse & Co., Beloit, Wis.
Martin, R. W., Otter Tail Power Co., Fergus Falls, Minn.
Master, W. R., Vickers, Inc., Detroit, Mich.
McAuliff, D., Sangamo Elec. Co., Springfield, Ill.
McBurney, C. E., Eastern Iowa Light & Power Co-op., Davenport, Ia.
McClary, L. R., Western Elec. Co., Chicago, Ill.
McDonald, F. X., Rose Polytechnic Inst., Terre Haute, Ind.
McGuire, F. D., Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
McVean, R. L., Detroit Edison Co., Detroit, Mich.
Medal, E. C., Commonwealth Edison Co., Chicago, Ill.
Mengel, H. F., Commonwealth Edison Co., Chicago, Ill.
Meyer, C. J., Consumers Power Co., Pontiac, Mich.
Michels, J. A., Teletype Corp., Chicago, Ill.
Mohr, T. E., The Louis Allis Co., Milwaukee, Wis.
Miller, D. G., Barber-Colman Co., Rockford, Ill.
Mitchell, C. T., Allis-Chalmers Mfg. Co., LaPorte, Ind.
Morris, G. T., Purdue Univ., W. Lafayette, Ind.
Morris, T. J., P. R. Mallory & Co., Indianapolis, Ind.
Moser, W. L., Standard Oil Co., Whiting, Ind.
Moses, K. L., Associated Factory Mutual Fire Insurance Cos., Chicago, Ill.
Moss, A. S., N. M. Mintz & Assoc., Chicago, Ill.
Mowery, R. W., Univ. of Illinois, Urbana, Ill.
Mullins, R., Public Service Co. of Northern Illinois, Joliet, Ill.
Nack, H. T., Jr., Appleton Elec. Co., Chicago, Ill.
Nelson, R. E., American Tel. & Tel. Co., Chicago, Ill.
Neumann, C. B., Milwaukee School of Engg., Milwaukee, Wis.
Nickel, F. E., Westinghouse Elec. Supply Co., Flint, Mich.
Niles, R. A., Wisconsin Elec. Power Co., Milwaukee, Wis.
Noland, A. R., University of Ill., Urbana, Ill.
Nowakowski, R. S., Louis Allis Co., Milwaukee, Wis.
Ocnaschek, F. J., Collins Radio Co., Cedar Rapids, Iowa
Oldenkamp, J. L., General Elec. Co., Ft. Wayne, Ind.
Oleson, M. W., Univ. of Wisconsin, Madison, Wis.
Opryszek, E. J., John Morrell & Co., Ottumwa, Iowa
Ozarka, R. J., Western Elec. Co., Chicago, Ill.
Palm, H. A., Jr., Western Union Tel. Co., Chicago, Ill.
Peck, L. B., General Elec. X-Ray Corp., Milwaukee, Wis.
Peters, C. N., Wisconsin Elec. Power Co., Milwaukee, Wis.
Peterson, R. W., Halliburton Oil Well Cementing Co., Fairfield, Ill.
Popp, J. A., Motorola, Inc., Chicago, Ill.
Porphir, F. G., City of Detroit Public Lighting Comm., Detroit, Mich.
Powers, W. E., Public Service Co. of No. Illinois, Chicago, Ill.
Preston, R. M., Commonwealth Edison Co., Chicago, Ill.
Pummer, L., Line Material Co., South Milwaukee, Wis.
Ramminger, R. B., Square D Company, Milwaukee, Wis.
Rathbun, E. R., Jr., Iowa State College, Ames, Iowa
Reedy, W. J., Cutler-Hammer, Inc., Milwaukee, Wis.
Reeves, R. F., Iowa State College, Ames, Iowa
Rhine, W. C., Cutler-Hammer, Inc., Milwaukee, Wis.
Rice, D. H., The Louis Allis Co., Milwaukee, Wis.
Rice, H. O., American Television & Radio, St. Paul, Minn.
Rieland, P. A., Allis-Chalmers Mfg. Co., West Allis, Wis.
Rolfes, D. H., General Elec. X-Ray Corp., Minneapolis, Minn.
Rose, F. M., Minnkota Power Co-op., Grand Forks, N. Dak.
Ross, D. C., Purdue Univ., Lafayette, Ind.
Ross, H. M., Motorola Inc., Chicago, Ill.
Roth, E. M., Public Service Co. of Northern Illinois, Northbrook, Ill.
Ruderman, M., Detroit Arsenal, Centerline, Mich.
Ruedy, A. C., Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Schaeve, D. K., Barber-Colman Co., Rockford, Ill.
Scheffers, R. E., Joslyn Mfg. & Supply Co., Chicago, Ill.
Schlotter, M., Universal Atlas Cement Co., Buffington, Ind.
Schmid, L. C., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Schmidt, D. P., The Pyle-Natl. Co., Chicago, Ill.
Schuster, D. J., Dietz Elec. Co., Milwaukee, Wis.
Scott, J. V., Commonwealth Edison Co., Chicago, Ill.
Secor, G., Cutler-Hammer, Inc., Milwaukee, Wis.
Seegmiller, W. R., General Elec. Co., Ft. Wayne, Ind.
Seidl, A. C., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Seng, R. A., Lee Engg. & Mfg. Co., Milwaukee, Wis.
Shirey, E. L., Chicago District Elec. Generating Corp., Hammond, Ind.
Skar, N. D., Associated Factory Mutual Fire Ins. Co., Chicago, Ill.
Smatlik, V., Illinois Bell Tel. Co., Chicago, Ill.
Smiley, W. D., Square D Co., Milwaukee, Wis.
Smith, W. H., Weltronic Co., Detroit, Mich.
Sommers, A. P., Commonwealth Edison Co., Chicago, Ill.
Soo Hoo, H., Detroit Edison Co., Detroit, Mich.
Spink, R. W., Cutler-Hammer, Inc., Milwaukee, Wis.
Spooner, M. G., Standard Oil Co., Whiting, Ind.
Stanko, E. S., Detroit Arsenal, Centerline, Mich.
Stephens, W. E., Commonwealth & Southern Corp. (N. Y.), Jackson, Mich.
Subar, E. D., Consumers Power Co., Jackson, Mich.
Swanson, D. H., Public Service Co. of No. Illinois, Kankakee, Ill.
Swenson, C. J., Commonwealth Edison Co., Chicago, Ill.
Swenson, P. E., Cutler-Hammer, Inc., Milwaukee, Wis.
Syler, R. T., Westinghouse Elec. Corp., Chicago, Ill.
Syrjamaki, E. M., Consumers Power Co., Jackson, Mich.
Taylor, L. D., Northwest Airlines, Inc., St. Paul, Minn.
Taylor, R. H., Illinois Bell Tel. Co., Chicago Heights, Ill.
Temme, H. C., United Light & Railways Service Co., Davenport, Iowa
Thayer, L. L., Michigan Bell Tel. Co., Detroit, Mich.
Thompson, D. F., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Timm, L. C., Keith Elec. Construction Co., Des Moines, Iowa
Tun, H. T., Commonwealth Edison Co., Chicago, Ill.
Verhein, D. H., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Vig, K. S., Fairbanks Morse & Co., Beloit, Wis.
Wanasek, R. L., A.B.C. Tire & Supply Co., Milwaukee, Wis.
Wark, J. R., Indianapolis Power & Light Co., Indianapolis, Ind.
Wasson, G. W., Square D Co., Detroit, Mich.
Weisz, W. J., Motorola, Inc., Chicago, Ill.
Whitsitt, L. E., Allis-Chalmers Co., Milwaukee, Wis.
Williams, J. L., Jr., Public Service Co. of Northern Illinois, Glencoe, Ill.
Williams, O., Kuhlman Elec. Co., Bay City, Mich.
Williamson, D. S., Jr., Aluminum Ore Co., East St. Louis, Ill.
Willis, C. P., Jr., Consumers Power Co., Jackson, Mich.
Wittenberg, H., Control Corp., Minneapolis, Minn.
Wolf, A. E., Chicago Transit Authority, Chicago, Ill.
Wolf, I. B., Copco Steel & Engg. Co., Detroit, Mich.
Wolters, R. F., Harnischfeger Corp., Milwaukee, Wis.
Zartman, J. D., R-B-M Mfg. Corp., Lagansport, Ind.
Zilis, G. S., Illinois Bell Tel. Co., Chicago, Ill.
Zobel, E. R., Zobel Sales Co., Grand Forks, N. Dak.

6. North Central

Balliette, G. H., Square D Co., Omaha, Nebr.

Braitman, A., Bureau of Reclamation, Denver, Colo.
Chap, R. A., U. S. Bureau of Reclamation, Casper, Wyo.
Cole, J. H., Omaha Public Power District, Omaha, Nebr.
Corbin, D. N., Radio Specialists Co., Denver, Colo.
Cottle, R. J., Cheyenne Lt. Fuel & Pr. Co., Cheyenne, Wyo.
Doughty, F. L., 1546 Broadway, Boulder, Colo.
Dunbar, W. R., Univ. of Colorado, Boulder, Colo.
Dunn, O. E., Jr., Homestake Mining Co., Lead, S. Dak.
Ebersole, L. K., Colorado Interstate Gas Co., Colorado Springs, Colo.
Hayden, H. M., 3710 Teller St., Wheat Ridge, Colo.
Hoyer, H. Z., Omaha Public Power District, Omaha, Nebr.
Johnston, R. W., Board of Public Works, Beatrice, Nebr.
Kaplan, I. I., U. S. Bureau of Reclamation, Denver, Colo.
Kiesel, K. A., State Highway Dept., Grand Junction, Colo.
Limerick, M. D., U. S. Bureau of Reclamation, Denver, Colo.
Livesay, J. C., Colorado Central Power Co., Englewood, Colo.
Mason, L. J., Univ. of Colorado, Boulder, Colo.
McAdams, W. G., Colorado Central Power Co., Englewood, Colo.
McCormick, H. H., Public Service Co. of Colorado, Denver, Colo.
Pattee, C. H., Gates Rubber Co., Denver, Colo.
Peterman, R. W., Cheyenne Light, Fuel & Power Co., Cheyenne, Wyo.
Piper, A. E., Stanolind Oil & Gas Co., Midwest, Wyo.
Reiquam, E. T., U. S. Bureau of Reclamation, Denver, Colo.
Reynolds, L. E., Corps of Engrs., Omaha, Nebr.
Riter, G. W., American Surety Co., Omaha, Nebr.
Tressler, R. W., The Gates Rubber Co., Denver, Colo.
Twombly, J. C., Univ. of Colorado, Boulder, Colo.
Usher, T. E., Univ. of Colorado, Boulder, Colo.
Wilson, J. L., Jr., Omaha Public Power District, Omaha, Nebr.

7. South West

Adams, F. G., Anaconda Wire & Cable Co., Kansas City, Mo.
Allen, G. E., Jr., American Tel. & Tel. Co., Albuquerque, N. Mex.
Allen, R. C., Texas Elec. Service Co., Wichita Falls, Tex.
Alles, J. B., Houston Lighting & Power Co., Houston, Tex.
Amos, J. C., Public Service Co. of Oklahoma, Tulsa, Okla.
Anderson, R. L., Texas Elec. Service Co., Ft. Worth, Tex.
Anderson, W. L., McCollum Exploration Co., Houston, Tex.
Armstrong, R. W., Geophysical Service, Inc., Dallas, Tex.
Atkins, C. P., A. B. Chance Co., Centralia, Mo.
Autenrieth, J. R., Alamo Refining Co., Sweeny, Tex.
Barber, G., Central Power & Light Co., Corpus Christi, Tex.
Bardwell, J. N., Sound-Photo Equipment Co., Lubbock, Tex.
Basham, R., 321 So. Shaw St., Richmond, Mo.
Beard, R. S., Texas Elec. Service Co., Ft. Worth, Tex.
Birge, M. C., Emerson Elec. Mfg. Co., St. Louis, Mo.
Bishop, H. L., Phillips Oil Co., Kansas City, Kans.
Bivins, E. M. S. (Mrs.), Texas Elec. Service Co., Ft. Worth, Tex.
Bivins, G. P., Civil Aeronautics Admin., Ft. Worth, Tex.
Blackert, R. O., Western Union Tel. Co., Kansas City, Mo.
Bleck, F. L. (Student), Univ. of Texas, Austin, Tex.
Boatright, J. A., Okla. Gas & Elec. Co., Muskogee, Okla.
Brawner, C. A., Jr., Continental Electronics Mfg. Co., Dallas, Tex.
Brown, B. L., Sverdrup & Parcel, St. Louis, Mo.
Buettner, E. F., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Burmeier, J. C., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Burns, J. H., Univ. of California, Albuquerque, N. Mex.
Buttles, W. H., Production Engg. Labs., Oklahoma City, Okla.
Calori, A. H., Jr., Oklahoma City Air Materiel Area, Oklahoma City, Okla.
Chapman, L. W., Floyd County Rural Elec. Coop. Inc., Floydada, Tex.
Cochran, J. B., Halliburton Oil Well Cementing Co., Hobbs, N. Mex.
Coleman, G. P., Public Service Co. of Okla., Tulsa, Okla.
Corte, F. G. D., Continental Oil Co., Rio Grande City, Tex.
Cox, R. C., Phillips Oil Co., Borger, Tex.
Cunningham, J. H., Westinghouse Elec. Corp., St. Louis, Mo.
Dallabetta, J. P., Phillips Petroleum Co., Phillips, Tex.
Dean, L. M., Jr., Public Service of Oklahoma, Tulsa, Okla.
Dinter, H. A., Jr., Southwestern Bell Tel. Co., Austin, Tex.
Davis, C. E., Union Elec. Co. of Mo., St. Louis, Mo.
Dudley, C. E., Southern Alkali Corp., Corpus Christi, Tex.
Dunn, J. A., General Elec. Supply Corp., Kansas City, Mo.
Dlouhy, G. J., I.B.M. Corp., St. Louis, Mo.
De Salme, R. A., Meletio Elect. Supply Co., Dallas, Tex.
Elmendorf, E. H., Gasoline Plant Const. Corp., Hawkins, Tex.
Ferguson, D. E., Black & Veatch, Kansas City, Mo.
Friedrich, R. B., Kansas City Power & Light Co., Kansas City, Mo.
Gale, J. G., Sverdrup & Parcel, Inc., St. Louis, Mo.
Gibbs, B. J., Wagner Elec. Corp., St. Louis, Mo.
Giles, A. B., Baldwin Locomotive Works, St. Louis, Mo.
Gilliland, O., Kansas State College, Manhattan, Kans.
Goeser, J. A., Central Power & Light Co., Corpus Christi, Tex.
Govro, M. A., Univ. of Missouri, Columbia, Mo.
Graham, W. R., Texas Elec. Service Co., Big Spring, Tex.
Griffin, P. T., Southwestern Public Service Co., Amarillo, Tex.
Granosky, A. J., Board of Public Utilities, Kansas City, Kans.
Grote, L. D., St. Joseph Light & Power Co., St. Joseph, Mo.
Guthrie, J. E., American Tel. & Tel. Co., Albuquerque, N. Mex.
Heiman, H. D., Southern X-Ray Engg. Co. Inc., Houston, Tex.
Heinrich, W. W., Phillips Oil Co., Borger, Tex.
Hungate, J. W., Univ. of California, Albuquerque, N. Mex.
Jeffery, E. K., Freese & Nichols, Consulting Engrs., Ft. Worth, Tex.
Kaplan, J., John Ledbetter Elec. Co., St. Louis, Mo.
Kohlbacher, F. A., Wagner Elec. Corp., St. Louis, Mo.
Lamb, R. B., Jr., Oklahoma A & M College, Stillwater, Okla.
Ledwig, A. J., Anderson-Young Elec. Co., Lubbock, Tex.
Levander, D. H., Univ. of Texas, Austin, Tex.
Lively, L. V., 322 S. McGee St., Borger, Tex.
Long, J. C., Texas Elec. Service Co., Big Spring, Tex.
Lundelius, O. E., Jr., Crouse-Hinds Co., Houston, Tex.
Lyon, W. L., Jr., El Paso Elec. Co., El Paso, Tex.
Magee, J. F., Halliburton Oil Well Cementing Co., Gainesville, Tex.
Magoffin, S., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Martin, H. W., (Student), Culver-Stockton College, Canton, Mo.
Mathews, W. A., Bussmann Mfg. Co., St. Louis, Mo.
McInnes, M. P., Oklahoma A & M College, Stillwater, Okla.
McNeil, G. R., Continental Oil Co., Enid, Okla.
Meyer, B. W., Southwestern Bell Tel. Co., Oklahoma City, Okla.
Miller, W. B., Houston Lighting & Power Co., Houston, Tex.
Moss, D. G., Kansas State College, Manhattan, Kans.
Mueller, P. T., McDonnell Aircraft Corp., St. Louis, Mo.
Murray, R. E., St. Louis Public Schools, St. Louis, Mo.
Mut, S. C., The Atlantic Refining Co., Dallas, Tex.
Nicholas, J. F., Univ. of California, Albuquerque, N. Mex.
Nolte, J. L., Union Elec. Co. of Missouri, St. Louis, Mo.
Oatman, A. C., Jr., Black & Veatch, Kansas City, Mo.
Oliver, J. K., Wagner Elec. Corp., St. Louis, Mo.
Olsen, M. M., I.B.M., St. Louis, Mo.
Olson, A. D., Halliburton Oil Well Cementing Co., Shawnee, Okla.
O'Reilly, H. V., Dallas Power & Light Co., Dallas, Tex.
Osborn, R. J., Sinclair Refining Co., Independence, Kans.
Osseck, P. R., I.B.M. Corp., St. Louis, Mo.
Owen, R. B., Emerson Elec. Mfg. Co., St. Louis, Mo.
Palacios H., Luis, Mexican Light & Power Co. Ltd., Mexico, Federal District, Mexico
Pallardy, R. N., Union Elec. Co. of Mo., St. Louis, Mo.
Parmenter, E. G., Black & Veatch, Kansas City, Mo.
Peck, A. E., Consolidated Vultee Aircraft Corp., Ft. Worth, Tex.
Perez, D. B., Mexican Light & Power Co., Mexico, Federal District, Mexico
Pettersen, R. W., Geophysical Service Inc., Dallas, Tex.
Pittman, P., Jr., The Gilbert X-Ray Co., Dallas, Tex.
Ploch, H. A., William Orrison Engrs. & Assoc., San Antonio, Tex.
Powers, H. P., Orrison Engrs. & Assoc., San Antonio Tex.
Pultman, L., McDonnell Aircraft Corp., Robertson, Mo.
Radford, J. L., H. B. Wells, Dallas, Tex.
Rains, L. A., I.B.M., St. Louis, Mo.
Richardson, D. D., Phillips Petroleum Co., Bartlesville, Okla.
Roberts, H. C., Jr., Century Elec. Co., St. Louis, Mo.
Robinson, D. G., Sverdrup & Parcel, Inc., St. Louis, Mo.
Ross, J., Oklahoma A. & M. College, Stillwater, Okla.
Scherwitz, W. W., Lockwood & Andrews, Houston, Tex.
Schwarz, R. M., Emerson Elec. Mfg. Co., St. Louis, Mo.
Seifert, R. J., American Tel. & Tel. Co., St. Louis, Mo.
Shaw, R., Wagner Elec. Corp., St. Louis, Mo.
Shelton, J. T., Boeing Airplane Co., Alamogordo, N. Mex.
Shinkle, H. A., Jr., Kansas City Power & Light Co., Kansas City, Mo.
Shouse, J. C., Phillips Oil Co., Okmulgee, Okla.
Sisk, H. D., Wagner Elec. Co., St. Louis, Mo.
Spieker, L. J., Geophysical Service, Inc., Dallas, Tex.
Spradling, G. V., Emerson Elec. Mfg. Co., St. Louis, Mo.
Stephenson, T. B., Jr., Schlumberger Well Surveying Corp., Abilene, Tex.
Stepoway, T., Schlumberger Well Surveying Corp., Falfurrias, Tex.
Stevenson, J. M., (re-election), 152½ Pine St., Abilene, Tex.
Stewart, T. L., Shell Pipe Line Corp., Houston, Tex.
Stout, W. A., The Texas Pipe Line Co., Houston, Tex.
Tatum, D. F., Southwestern Public Service Co., Roswell, N. Mex.
Taylor, E. A., Jr., Phillips Oil Co., Okmulgee, Okla.
Taylor, J. R., Public Service Co. of Okla., Tulsa, Okla.
Thompson, B. R., Standard Elec. Mfg. Co., Dallas, Tex.
Thompson, W. G., Sverdrup & Parcel, Inc., St. Louis, Mo.
Townsend, P. H., Southwestern Bell Tel. Co., Dallas, Tex.
Wade, V. D., Texas Tech. College, Lubbock, Tex.
Watson, G. W., Carter Oil Co., Lincoln, Nebr.
Watson, S. E., Jr., McDonnell Aircraft Corp., St. Louis, Mo.
Wheelock, J. T., General Elec. X-Ray Corp., Dallas, Tex.
Willis, T. A., Jr., Texas Elec. Service Co., Ft. Worth, Tex.
Wilson, N. D., Great Lakes Pipe Line Co., Kansas City, Mo.
Wooldridge, D. P., Dallas Power & Light Co., Dallas, Tex.

8. Pacific

Adler, J. A., Naval Radiological Defense Lab., San Francisco, Calif.
Alexander, R. C., Western Precipitation Corp., Los Angeles, Calif.
Allen, L. W., NACA-Ames Lab., Moffett Field, Calif.
Anderson, J. W., Union Oil Co. of California, Compton, Calif.
Anderson, W. F., Arizona State College, Tempe, Ariz.
Anderson, W. R., California State Polytech. College, San Luis Obispo, Calif.
Babcock, R. M., Ralph M. Parsons Co., Los Angeles, Calif.
Ballou, J. K., Standard Oil Co. of Calif., San Francisco,
Bare, J. B., I.B.M. Corp., San Francisco, Calif.
Bates, A. E., Westinghouse Elec. Corp., Los Angeles, Calif.
Beam, B. H., Ames Aeronautical Lab., Moffett Field, Calif.
Beatty, J. W., Dept. of Water & Power, Los Angeles, Calif.
Cadwell, H. B., Pacific Tel. & Tel. Co., San Francisco, Calif.
Campbell, B. L., Univ. of California, Berkeley, Calif.
Chambers, G. R., Dr. R. T. Knapp, Pasadena, Calif.
Chamlee, R. D., Southern California Edison Co., Los Angeles, Calif.
Chandler, C. L., I.B.M. Corp., Los Angeles, Calif.
Cohon, J. L., Southern California Edison Co., Los Angeles, Calif.
Cole, D. B., Dept. of Water & Power, Los Angeles, Calif.
Conner, W. M., Thomas Machinery Co., Los Angeles, Calif.
Croudace, J. C., Arabian American Oil Co., San Francisco, Calif.
Dahlstrom, R. G., Dept. of Water & Power, Los Angeles, Calif.
Dean, E. S., Jr., Pacific Gas & Elec. Co., Oakland, Calif.
Deguchi, R., Bureau of Reclamation, Kingman, Ariz.
Dethlefsen, D. G., Stanford Univ., Stanford, Calif.
Deyo, A. E., Western Union Tel. Co., Los Angeles, Calif.
Dock, F. W., Dept. of Water & Power, City of Los Angeles, Independence, Calif.
Duncan, D. O., U. S. Bureau of Reclamation, Redding, Calif.
Duncan, H. W., Bechtel Corp., San Francisco, Calif.
Engelbart, D. C., Ames Aeronautical Lab., Moffett Field, Calif.
Evans, C. B., 4255 Falcon, Long Beach, Calif.
Farrell, E. J., Jr., Long Beach Naval Shipyard, Long Beach, Calif.
Fickes, D. C., U. S. Elec. Motors, Inc., Los Angeles, Calif.
Finch, J. W., Naval Shipyard, Long Beach, Calif.
Finkelstein, L. I., U. S. Naval Ord. Test Station, Pasadena, Calif.
Fulkerson, A. C., North American Aviation, Inc., Los Angeles, Calif.
Garber, M., Consolidated Engr. Corp., Pasadena, Calif.
Graham, J. W., Pacific Gas & Elec. Co., San Francisco, Calif.
Gustin, W., California-Pacific Utilities Co., Susanville, Calif.
Hacker, H. H., 214 N. Crescent Dr., Beverly Hills, Calif.
Hansen, G. L., Douglas Aircraft Co., Santa Monica, Calif.
Hartshorne, R., Jr., General Elec. Co., San Francisco, Calif.
Hitt, M. O., U. S. Naval Shipyard, Long Beach, Calif.
Hoagland, A. S., Univ. of California, Berkeley, Calif.
Holloman, C. J., Western Union Tel. Co., San Francisco, Calif.
Hone, J. V., Pacific Gas & Elec. Co., Dinuba, Calif.
Hood, K. C., Central Arizona Light & Power Co., Phoenix, Ariz.
Hubert, F. J., Southern California Edison Co., Alhambra, Calif.
Huebsch, D. L., Dept. of Water & Power, Los Angeles Calif.
Inami, F. K., 802 Washington Ave., Madera, Calif.
Jaski, T., Div. of San Francisco Bay Toll Crossings, San Francisco, Calif.
Jensen, J. A., Pacific Gas & Elec. Co., Oakland, Calif.
Keller, E. L. (re-election), So. California Edison Co., Los Angeles, Calif.
Kelly, H. M., Dept. of Water & Power, Los Angeles, Calif.
Keppel, R. A., Hughes Aircraft, Culver City, Calif.
Kerhulas, A. T., Pacific Gas & Elec. Co., Oakland, Calif.
Klemens, W. P., Hoffman Radio Corp., Los Angeles, Calif.
Kono, S. M., Kistner, Curtis & Wright, Los Angeles, Calif.
Krapf, H. A., Dept. of Water & Power, Los Angeles, Calif.
Lafferty, J. W., Ira G. Perin Co., Los Angeles, Calif.
Lawson, J. H., Pacific Gas & Elec. Co., Emeryville, Calif.
Lilienthal, D. M., 300 E. 8th St., Los Angeles, Calif.
Logan, J. A., Jr., Douglas Aircraft Co., Inc., El Segundo, Calif.
Lomas, A. T., Pacific Gas & Elec. Co., San Francisco, Calif.
McGarvey, W., General Elec. Supply Corp., San Francisco, Calif.

McMillan, W. A., Pacific Tel. & Tel. Co., Berkeley, Calif.
McRuer, D. T., Northrop Aircraft Inc., Hawthorne, Calif.
Michael, W. T., Westinghouse Elec. Corp., Phoenix, Ariz.
Mikkelsen, W. B., Coast Counties Gas & Elec. Co., Santa Cruz, Calif.
Mills, J. J., Philco Corp., Mare Island, Calif.
Mokler, L. J., Zamboni Bros. Elec. Co., Paramount, Calif.
Monroe, F. M., Jr., Pacific Gas & Elec. Co., Oakland, Calif.
Moseley, J. A., Univ. of California, Santa Barbara, Calif.
Mueller, R. J., U. S. Bureau of Reclamation, Redding, Calif.
Myers, M. B., General Petroleum Corp., Los Angeles, Calif.
Newton, J. H., Pacific Fruit Express Co., San Francisco, Calif.
Norman, R. E., Calif. Elec. Power Co., Riverside, Calif.
Olson, C. L., U. S. Naval Ord. Test Station, Pasadena, Calif.
Parker, N. H., Westinghouse Elec. Corp., San Francisco, Calif.
Pasic, J. L., Jr., North American Aviation, Inc., Los Angeles, Calif.
Perry, H. R., Ames Aeronautical Lab., Moffett Field, Calif.
Perkel, D., Pacific Gas & Elec. Co., Oakland, Calif.
Peterson, W. H., Pacific Gas & Elec. Co., San Francisco, Calif.
Pines, H., Dept. of Water & Power, Los Angeles, Calif.
Plunk, W. R., Bureau of Reclamation, Phoenix, Ariz.
Pulskamp, J. J., Dept. of Water & Power, Los Angeles, Calif.
Rivett, R. C., State of Calif., Div. of Architecture, Sacramento, Calif.
Rodriguez, C. F., Jr., Burbank Broadcasters, Inc. (*KWIK*), Burbank, Calif.
Rosman, A. S., Aerojet Engg. Corp., Azusa, Calif.
Rotty, R. M., (Student), California Inst. of Tech., Pasadena, Calif.
Rynerson, D. E., U. S. Naval Shipyard, Long Beach, Calif.
Schiowitz, H. H., Naval Air Missile Test Center, North Hollywood, Calif.
Schlueter, G. R., General Elec. Co., Los Angeles, Calif.
Shoemaker, F. R., State Div. of Highways, Marysville, Calif.
Short, G. H., Westinghouse Mfg. & Elec. Corp., Sunnyvale, Calif.
Spencer, M. L., Jr., Pacific Gas & Elec. Co., Lakeport, Calif.
Spencer, J. T., Southern California Edison Co. Ltd., Los Angeles, Calif.
Steele, D. H., Stone & Webster Engg. Corp., Bakersfield, Calif.
Stephens, D. H., Northrop Aircraft, Inc., Hawthorne, Calif.
Strain, D. C., Natl. Technical Lab., South Pasadena, Calif.
Thormahlen, W. H., Dalmo Victor Co., San Carlos, Calif.
Turner, F. D., Bureau of Reclamation, Phoenix, Ariz.
Waldow, C. W., Westinghouse Elec. Corp., Los Angeles, Calif.
Warren, J. E., Calif. Research Corp., La Habra, Calif.
Welliver, C. L., Hughes Aircraft Co., Culver City, Calif.
Wells, O. H., Westinghouse Elec. Corp., San Francisco, Calif.
Wesley, E. J., Naval Radiological Defense Lab., San Francisco, Calif.
Whilldin, F. W., San Diego Gas & Elec. Co., San Diego, Calif.
Woodson, T. S., Douglas Aircraft Co., El Segundo, Calif.
Young, B. U., Westinghouse Elec. Corp., San Francisco, Calif.

9. North West

Adolfson, H., Boeing Aircraft Co., Seattle, Wash.
Allen, S. R., (re-election), Bonneville Power Admin., Portland, Oreg.
Armstrong, T. W., Jr., Boeing Aircraft Co., Seattle, Wash.
Asbenbrenner, R. L., Bureau of Reclamation, Great Falls, Mont.
Bayerd, F. G., Boeing Aircraft Co., Seattle, Wash.
Bell, D. M., Bonneville Power Admin., Portland, Oreg.
Bishop, L. E., General Elec. Co., Richland, Wash.
Broehl, D. J., Portland General Elec. Co., Portland, Oreg.
Burdic, W. S., Oregon State College, Corvallis, Oreg.
Burnett, M. E., Machinery Designers, Inc., Hoquiam, Wash.
Carden, G. K., Bureau of Reclamation, Coulee Dam, Wash.
Chrisman, A. M., Boeing Aircraft Co., Seattle, Wash.
Conner, M. R., Eoff Elec. Co., Portland, Oreg.
Cottrell, W. J. (re-election), 309 S. W. 3d Ave., Portland, Oreg.
Davenport, R. P., Montana Power Co., Great Falls, Mont.
Davis, W. W., Boeing Aircraft Co., Seattle, Wash.
Dawson, B. R., Electrical Equipment Mfgr., Seattle, Wash.
Devlin, J. R., Bonneville Power Admin., Vancouver, Wash.
Dickinson, M. W., Simpson Logging Co., Shelton, Wash.
Drechsel, L. G., General Elec. X-Ray Corp., Salt Lake City, Utah
Eacker, W. L. R., Washington Water Power Co., Spokane, Wash.
Elton, M. B., (re-election), Bonneville Power Admin., Portland, Oreg.
Fell, W. H., P.U.D. #1, Clark County, Vancouver, Wash.
Forsythe, J. E., U. S. Bureau of Reclamation, Coulee Dam, Wash.
Garris, G. C., Permanente Metals Corp., Mead, Wash.
Golden, C. L., Seattle City Light, Seattle, Wash.
Greene, G. K., Boeing Aircraft Co., Seattle, Wash.
Haig, A. S., Bonneville Power Admin., Portland, Oreg.
Havens, J. D., Boeing Aircraft Co., Seattle, Wash.
Hillas, M. G., U. S. Bureau of Reclamation, Coulee Dam, Wash.
Horner, F. S., Jr., Boeing Aircraft Co., Seattle, Wash.
Johnson, K. R., Bureau of Reclamation, Billings, Mont.
Jordan, R. S., 1406 W. Copper, Butte, Mont.
Keltner, W. W., The Pacific Tel. & Tel. Co., Seattle, Wash.
Knowles, E. L., Greene Elec. Furnace Co., Seattle, Wash.
Knox, R. F., Washington State College, Pullman, Wash.
Korp, J. E., Boeing Aircraft Co., Seattle, Wash.
Larson, L. D., Inland Empire Paper Co., Millwood, Wash.
Lavier, E. E., Jr., Bonneville Power Admin., Vancouver, Wash.
Markosian, H., Bureau of Reclamation, Coulee Dam, Wash.
McSherry, J. G., Boeing Aircraft Co., Seattle, Wash.
Montgomery, J. E., Boeing Aircraft Co., Seattle, Wash.
Mozer, H. M., Bonneville Power Admin., Portland, Oreg.
Nakahara, T., Bureau of Reclamation, Coulee Dam, Wash.
Nelson, B. K., Boeing Aircraft Co., Seattle, Wash.
Nelson, R. W., California Pacific Utilities Co., Baker, Oreg.
Ormsby, C. R., Bonneville Power Admin., Portland, Oreg.
Patten, L. M., Seattle City Lighting Dept., Seattle, Wash.
Pearce, J. M., Bonneville Power Admin., Portland, Oreg.
Pettit, J. M., Boeing Aircraft Co., Seattle, Wash.
Riem, W. R., Boeing Aircraft Co., Seattle, Wash.
Roberts, B. J., Boeing Aircraft Co., Seattle, Wash.
Rush, F. E., Bonneville Power Admin., Vancouver, Wash.
Samuelson, F. A., Portland General Elec. Co., Salem, Oreg.
Schaufelberger, F. G., Bonneville Power Admin., Vancouver, Wash.
Seidl, M. G., Boeing Aircraft Co., Seattle, Wash.
Severtson, D. M., U. S. Bureau of Reclamation, Coulee Dam, Wash.
Shennum, R. H., Montana State College, Bozeman, Mont.
Small, V. E., (re-election) Title & Trust Bldg. 424½ W. Lewis, Pasco, Wash.
Smith, H. W., Pacific Tel. & Tel. Co., Portland, Oreg.
Stanis, R. A., Utah Power & Light Co., Salt Lake City, Utah
Tweedale, J. W., Bonneville Power Admin., Portland, Oreg.
Vannelli, L. S., Jr., Weyerhaeuser Timber Co., Longview, Wash.
Walrabenstein, E. M., Boeing Aircraft Co., Seattle, Wash.
Yarbrough, L. L., Puget Sound Power & Light Co., Seattle, Wash.

10. Canada

Agnew, J. A., Bell Tel. Co. of Canada, Toronto, Ontario, Canada
Barclay, G. W., Hydro Elec. Power Comm. of Ontario, Toronto, Ontario, Canada
Blair, G. R., Canadian General Elec. Co., Toronto, Ontario, Canada
Bobyn, E. J., Defence Research Board (Canada), Quebec, Quebec, Canada
Bodo, A., Dominion Founderies & Steel Co., Hamilton, Ontario, Canada
Brett, P. A., English Elec. Co., St. Catharines, Ontario, Canada
Brodie, M. N., General Elec. Co. Ltd., Vancouver, British Columbia, Canada
Brown, B. F., McCarthy & Robinson Ltd., Toronto, Ontario, Canada
Buckles, F. G., Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada
Burgess, H. N., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Burnard, A. C., Canadian General Elec. Co., Toronto, Ontario, Canada
Campbell, C. E., British American Oil Co. Ltd., Clarkson, Ontario, Canada
Colquhoun, I. L., English Elec. Co. of Canada, Ltd., St. Catharines, Ontario, Canada
Coulby, W. G., Hydro-Elec. Pr. Comm. of Ont., Barrie, Ontario, Canada
Desroches, R., Canadian National Railways, Montreal, Quebec, Canada
Dundas, R. M., British Columbia Elec. Rly. Co., Ltd., Vancouver, British Columbia, Canada
Dunn, P. T., Fraser Cos. Ltd., Edmundston, New Brunswick, Canada
Evans, D. J., Canadian General Elec. Co., Ltd., Peterborough, Ontario, Canada
Flett, L. C., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Gilliver, J., Canadian General Elec., Toronto, Ontario, Canada
Gordon, E., Northern Elec. Co. Ltd., Montreal, Quebec Canada
Gray, J. C., Northern Elec. Co. Ltd., Montreal, Quebec, Canada
Green, W. F., H.E.P.C. of Ont., Toronto, Ontario, Canada
Harrison, R. S., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Hazelton, D. E., Canadian Westinghouse Co. Ltd., Hamilton, Ontario, Canada
Holman, M. R., Square D Co. of Canada, Ltd., Toronto, Ontario, Canada
Hopper, W. H., Amalgamated Elec. Corp., Toronto, Ontario, Canada
Houser, W. D., Canadian Westinghouse Co. Ltd., Hamilton, Ontario, Canada
Jamieson, W. M., Canadian General Elec. Co. Ltd., Montreal, Quebec, Canada
Jannaway, G. F., Hydro Elec. Power Comm. of Ont., Toronto, Ontario, Canada
Kobayashi, G. J., Stadler, Hurter & Co., Montreal, Quebec, Canada
Krumpotich, M. E., H.E.P.C., Toronto, Ontario, Canada
L'Anglais, F., Canadian General Elec. Co., Peterborough, Ontario, Canada
Lepine, M., Quebec Hydro-Elec. Comm., Montreal, Quebec, Canada
MacDougall, B. J. R., English Elec. Co. of Canada, St. Catharines, Ontario, Canada
Macenko, F., Canadian General Elec. Co., Toronto, Ontario, Canada
McCullum, J. B., Canadian Westinghouse Co., Hamilton, Ontario, Canada
McGregor, F. C., A. Edward Simpson, Vancouver, British Columbia, Canada
McGregor, J. L., Ontario Hydro Elec. Power Comm., Toronto, Ontario, Canada
McKee, W. R., Univ. of Toronto, Toronto, Ontario, Canada
McKinley, C. S., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
McLennan, J. R. B., Canadian Westinghouse Co. Ltd., Hamilton, Ontario, Canada
McLoughlin J. P. B., H.E.P.C. of Ontario, Toronto, Ontario, Canada
McNeill, R. W., Northwest Industries, Edmonton, Alberta, Canada
McWilliams, L., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
Miller, I. B., English Elec. Co. of Canada, St. Catharines, Ontario, Canada
Nastich, M., Ontario Hydro-Elec. Comm., Toronto, Ontario, Canada
Naylor, T. K., Canadian General Elec. Co. Ltd., Peterborough, Ontario, Canada
Nixon, R. S., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Payer, R. L., Aluminum Co. of Canada, Montreal, Quebec, Canada
Poirier, R. E., Central Elec, Shawinigan Falls, Quebec, Canada
Pukalo, W., Canadian General Elec. Co., Toronto, Ontario, Canada
Quan, B., Mathers & Haldenby, Toronto, Ontario, Canada
Raymond, H. N., Canadian General Elec. Co. Ltd., Toronto, Ontario, Canada
Robertson, S. A. M., Canadian General Elec. Co., Toronto, Ontario, Canada
Schurter, M. K., Federal Wire & Cable Co., Guelph, Ontario, Canada
Scrimgeour, J. H. C., Canadian General Elec. Co., Peterboro, Ontario, Canada
Shanahan, W. B., Canadian Westinghouse Co. Ltd., Hamilton, Ontario, Canada
Sumpton, M. G., English Elec. Co. of Canada, St. Catharines, Ontario, Canada
Takeda, G., Canadian General Elec. Co. Ltd., Toronto, Ontario, Canada
Watson, E. R. (Miss), Bell Tel. Co. of Canada, Montreal, Quebec, Canada
Watson, H. M., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Wheatley, G. H., Canadian General Elec. Co., Peterborough, Ontario, Canada
Wood, W. R. M., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada

Elsewhere

Aimer, H. K., A. Reyrolle & Co. Ltd., Hebburn, Co. Durham, England
Bhandari, J. N., Indian Inst. of Science, Bangalore, India
Bisaria, J. N., Indian Inst. of Science, Bangalore, India
Camargo, F. deB., The São Paulo T. Light & Power Co., Ltd., São Paulo, Brazil, South America
Glover, B. W., Standard Telephones & Cables, Ltd., London, England
Gupta, D., Hydro-Elec. Grid, Roorkee, U. P., India
Hage, W. G., Pearl Harbor Naval Shipyard, Honolulu, Hawaii
Mercado Cruz, R. Z., P. O. Box 452, Arecibo, Puerto Rico
Pardo, M., Tablas 20, Granada, Spain
Pitt, W. H., New Zealand Govt. Hydro-Elec. Dept. Hamilton, New Zealand
Richa, E. A., F. Icaza & Co., Panama, R. P.
Roed, P., Norsk Hydro, Solligt, Oslo, Norway
Rout, G. C., Indian Inst. of Science, Bangalore, India
Row Kavi, S. J., Basant Film Distributors, Bombay, India
Rubio R., E. A., Cuban Tel. Co., Habana, Cuba
Santisteban, J. A., Elec. Distributors Co., Inc., Santurce, Puerto Rico
Santos, P. J., Dalmau Co. por A, Ciudad Trujillo, Dominican Republic
Scholey, D., Bruce Peebles & Co. Ltd., Edinburgh, Scotland
Speedy, C. B., Sydney Univ., Sydney, Australia
Uldall-Hansen, S., Thomas B. Thrige, Odense, Denmark
Vila, I. G., Puerto Rico Water Resources Authority, Santurce, Puerto Rico
Woodhall, J. T., English Elec. Co., Ltd., Stafford, England

Total to grade of Associate
United States, Canada, and Mexico 1,520
Elsewhere, 22

OF CURRENT INTEREST

First Pan American Congress on Engineering Has Broad Program

The achievement of personal contact among engineers, and the study of engineering problems common to the two American continents are the primary objectives of the First Pan American Congress to be held in Rio de Janeiro, Brazil, July 15–24, 1949. The congress will be preceded by a meeting of engineers in São Paulo, July 9–13.

In the United States, one of the organizations actively at work in making preparations for the congress is the Engineers Joint Council which comprises five engineering societies, the AIEE, the American Institute of Mining and Metallurgical Engineers, the American Society of Civil Engineers, the American Institute of Chemical Engineers, and the American Society of Mechanical Engineers. Specifically, it is the council's subcommittee for participation in the Pan American congress, which is engaged in making the preparations.

Host for the engineers attending the congress will be the South American Union of Engineering Associations. Deadline for submission of papers to be presented is April 30, 1949.

The congressional agenda has been made broad in scope, so as to encourage the submission of a large number and variety of papers. Nine general topics will be included in the agenda. These are: transportation and communications; construction; power; urban and rural engineering; sanitary engineering; industrial engineering; mining engineering and geology; the teaching of engineering; and miscellaneous subjects.

Under the heading of transportation and communications, papers dealing with railway, highway, maritime, river and lake, and air transportation will be presented. In addition, there will be a discussion of telecommunications.

The session on construction will consider foundations, structures, and the elements of building construction.

Water, electricity, and various kinds of fuels are the energy sources that will be discussed in the symposium on power.

City planning, urban housing, public utilities, and city traffic are some of the problems to be covered in the session on urban and rural engineering. The rural aspects of the subject to be discussed include mechanization of agriculture, soil protection and improvement, and forest preservation.

The symposium on sanitary engineering will consider problems related to water supply, storm conditions, pollution of inland waters and bathing beaches, disposal of wastes, hospitals and cemeteries, rural sanitation.

The metallurgical, mechanical, extractive and processing, and chemical industries will come up for discussion in the session on industrial engineering. Mineral resources, prospecting for ores, mining legislation, private and public enterprise in the mining industry, and modern means of obtaining geological data will be considered under the heading, mining engineering and geology.

In the symposium dealing with the teaching of engineering, there will be discussions on the training of teachers, scholarships, and the interchange of studies on engineering educational problems in the American nations.

All of the symposia will be characterized by summaries of the conditions existing in the participating countries, with regard to the particular topic being discussed.

Mobile Generators Heat Centralia Homes

During the most severe ice storm Centralia, Mo., has experienced since 1937, auxiliary generators of the A. B. Chance Company's power-control unit were called upon to supply power to heat the city's homes. The generator set, normally used to supply power for controls and lighting for the company's mobile test laboratory, can be tapped directly for 110- and 220-volt single-phase loads for emergency use

Chance Company Founder Dies. A. B. Chance, chairman of the board of the A. B. Chance Company, Centralia, Mo., died February 8, 1949. A native of Centralia, Chance was born May 26, 1873. As a young man, he developed several devices for the improvement of telephone service. He also helped to establish Centralia's first telephone exchange, and designed an automatic room-calling apparatus for use in hotels. The A. B. Chance Company, founded by Chance in 1907, has put out numerous time- and labor-saving items, which have improved construction methods. Notable among these was the Never-Creep guy earth anchor, which sparked the growth of his small manufacturing business. The company later became a major supplier of line-construction, maintenance, and operating equipment. In 1937 while Chance was president, the company acquired the Tips Tool Company of Taylorville, Ill., and moved the plant equipment to Centralia. In 1945, his manufacturing facilities were expanded further, when the company purchased the Bowie Switch Company of San Francisco, Calif., which now bears the A. B. Chance name.

Electricity Production Sets Record for 1948

Energy production by electrical utilities during the year 1948 set a new record of 282,594,459,000 kilowatt-hours, an increase of 10.5 per cent over the previous high reached in 1947, the Federal Power Commission reported recently, as it released preliminary figures in its "Production of Electric Energy in the United States" series.

The year-end installed capacity of utiilty generating plants totaled 56,463,509 kw, a net gain of 4,141,502 kw during the year. Utility and industrial capacity totaled 69,485,881 kw at the end of 1948, and combined utility and industrial production of 336,335,478,000 kilowatt-hours for the year was 9.4 per cent above 1947. The year's industrial production totaled 53,741,019,000 kilowatt-hours.

During December 1948, production of

energy by electrical utilities totaled 25,687,915,000 kilowatt-hours. This is the highest monthly production on record, exceeding the previous record of October 1948 by about 1.3 billion kilowatt-hours or 5.5 per cent. It also exceeded December 1947 production by 9.2 per cent.

Water power plants produced 7,466,584,000 kilowatt-hours in December, an increase of 16.3 per cent over the monthly production of a year ago. December water-power output increased from 27.3 per cent last year, to 29.1 per cent this year. Fuel plants produced 18,221,331,000 kilowatt-hours during December. Reports received by the commission indicate that there was a net increase of 756,583 kw in the installed capacity of generating plants in utility service during December.

Industrial production, including generation by railway and railroad plants was 4,742,820,000 kilowatt-hours in December, an increase of 5.6 per cent over the same month last year. Total industrial generating capacity was 13,022,372 kw at the end of December 1948. Combined utility and industrial production during December was 8.6 per cent above the same month last year.

The report is compiled from data filed with the commission by electrical utilities and industrial plants of the United States, and may be obtained from the Federal Power Commission, Washington, D. C., for five cents.

Engineers Joint Council Approves Constitution, Votes New Officers

That the representatives of all the constituent societies had concurred on the revised draft of the constitution for the Engineers Joint Council was reported at a council meeting held February 7. The proposed constitution then was referred back to the five participating societies, the AIEE, the American Society of Civil Engineers (ASCE), the American Institute of Mining and Metallurgical Engineers (AIME), the American Society of Mechanical Engineers (ASME), and the American Institute of Chemical Engineers (AIChE), for official approval. J. E. Housley, H. H. Henline, and James F. Fairman represented the AIEE at the council meeting.

Following consideration of the constitution, council officers for the year 1949 were elected. As a result of the voting, R. E. Dougherty (past-president ASCE) became president of the council, W. N. Carey (executive council, ASCE), secretary, Scott Turner (past-president, AIME), vice-president, and E. L. Chandler (assistant secretary, ASCE), became treasurer.

Proposed congressional legislation was discussed also. Carey reported that the ASCE board of direction has decided to make every effort to improve the professional status of engineers in the military services, including the Reserve and National Guard. The ASCE recommendation that the Engineers Joint Council take similar steps was referred to the council's committee on national military establishment.

With regard to the Taft-Hartley labor act, the majority of the council expressed the opinion that the "professional provisions" of this act should be left intact in the legislation now pending and that no other issues should be included in the council's presentations to congressional committees.

It also was announced that the Senate bill, S-247, dealing with the proposed National Science Foundation, is identical with the unpassed Foundation legislation of the 80th Congress, which the Engineers Joint Council had fomerly endorsed. In response to the suggestion of the chairman of the science legislation panel that the council revise the list of recommended candidates for appointment to the National Engineering Foundation board, the representatives voted to request the panel chairman to make any revisions in the list which he deems suitable.

It was revealed that the council also had been active in affairs related to the administrative branch of the government. The council's national engineers committee had sent a circular letter to Paul Hoffman, head of the European Co-operation Administration, as well as to other Washington officials, offering council assistance in matters where the engineering profession might be of service. It also was announced that a "Washington Task Group," consisting of four engineers, had been formed to provide ready contact between governmental agencies and the national engineers committee.

Concerning a forthcoming report of the Hoover Commission, the council voted to review the report, when issued, and subsequently to develop a news release dealing with the aspects of the document which would directly concern the engineering profession.

It was reported also that the council's national water policy committee appeared to be making progress in interesting the National Research Council in the former's objectives.

With respect to international relations between engineers, it was revealed that the council's international relations committee was continuing to co-operate with the World Engineering Conference on the Cairo Congress, and that a large number of papers and personal representation from the United States appears assured for the Pan American Congress to be held next July. Plans of British civil, mechanical, and electrical institutions for reconvening the adjourned meeting of the London Conference and Western European and American Engineers were disclosed, the tentative date of the meeting to be September 25, 1949. It was the council's information that American representation would consist of not more than six representatives, the delegation comprising three at large, and the secretaries of the AIEE, the ASME, and the ASCE.

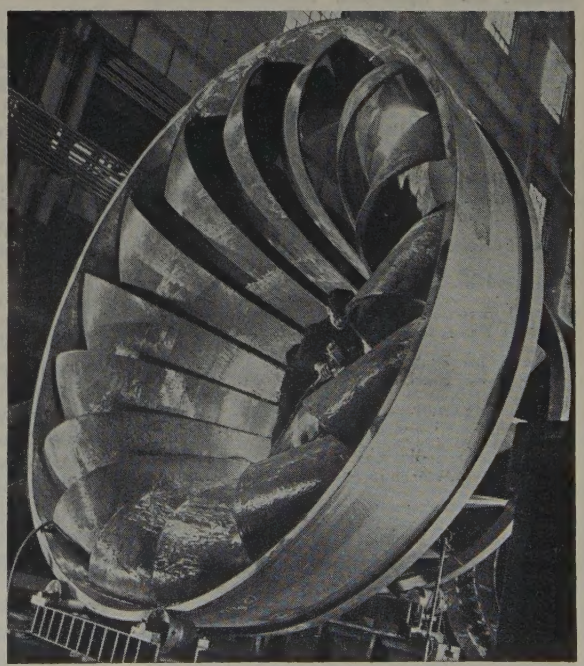
Towards the conclusion of the meeting, it was voted that the previously approved 1949 budget estimate for the council be reported to the constituent societies and their appropriations be requested under the formula set up in the new constitution.

The revised draft provides that financial support from the member societies be divided proportionately on the basis of dues income of each society. Funds also may be derived from any other source approved by the council. Furthermore, the constitution provides that finances will be used for specific purposes approved by the majority of the council, and that if a member society declines to contribute funds to a specific activity, then it will not be compelled to do so, the ratio of financial support being revised accordingly.

In addition to finances, the seven articles of the constitution deal with the council's objectives, membership requirements, officers' qualifications, duties, and terms, provisions for the formation of committees, ammendments, and the quorum.

The advancement of the general welfare of mankind through engineering, the promotion of co-operation among various branches of the engineering profession, and the development of sound public policies where the

Water - Wheel Runner for TVA Turbines



A worker smooths the vanes of a cast-steel Francis-type water-wheel runner for the first of four additional 35,000-horsepower 92-feet head hydraulic turbines now under construction in Allis-Chalmer shops for the Tennessee Valley Authority's Wilson Dam powerhouse. The runner will have a finished weight of about 95,000 pounds

services of engineers are involved, are the council's objectives, according to the constitution. By acting as a co-ordinating agency between the constituent societies and administering those activities approved by a majority of the member societies, the council hopes to achieve these objectives.

A proposal to publish an Engineers Joint Council pamphlet containing the provisions of the constitution, and a description of council committees and activities was referred to the committee on secretaries for study and report.

Future Meetings of Other Societies

American Gas Association. Production and chemical conference. May 23–25, 1949, Hotel New Yorker, New York, N. Y.

American Gear Manufacturers Association. Annual meeting. June 6–8, 1949, The Homestead, Hot Springs, Va.

American Management Association. Production meeting, April 12–13, 1949, Waldorf-Astoria Hotel, New York, N. Y. General management meeting, June 8–9, 1949, Hotel Statler, New York, N. Y.

American Society of Chemical Engineers. Tulsa, Okla., regional meeting, April 8–12, 1949.

American Society of Civil Engineers. Spring meeting. April 20–23, 1949, Oklahoma City, Okla.

American Society of Mechanical Engineers. 1949 Spring meeting, May 2–4, 1949, New London, Conn. Semiannual meeting, June 27–30, 1949, San Francisco, Calif.

American Society for Metals. 6th Western Metal Congress and Exhibition. April 11–16, 1949, Shrine Auditorium, Los Angeles, Calif.

Electrochemical Society. Spring meeting. May 4–7, 1949, Benjamin Franklin Hotel, Philadelphia, Pa.

Engineering Foundation. June 16, 1949, Engineering Societies Building, New York, N. Y.

Engineers Council of Houston. Second annual symposium. April 2, 1949, Rice Hotel, Houston, Tex.

Institute of Radio Engineers-Radio Manufacturers Association. Fourth annual Spring meeting. April 25–27, 1949, Benjamin Franklin Hotel, Philadelphia, Pa.

Instrument Society of America. Fourth annual Spring meeting. May 12–13, 1949, Royal York Hotel, Toronto, Ontario, Canada.

Michigan Safety Conference. 19th annual meeting. May 17–20, 1949, Hotels Leland, Shelvy, and Book-Cadillac, Detroit, Mich.

Midwest Power Conference. April 18–20, 1949, Sherman Hotel, Chicago, Ill.

National Association of Broadcasters. 27th annual convention. April 6–12, 1949, Hotel Stevens, Chicago, Ill.

National Association of Corrosion Engineers. Fifth annual conference and exhibition. April 11–14, 1949, Netherland-Plaza Hotel, Cincinnati, Ohio.

National District Heating Association. 40th annual meeting. May 24–27, 1949, The New Ocean House, Swampscott, Mass.

National Electrical Wholesalers Association. May 2–6, 1949, Netherland-Plaza Hotel, Cincinnati, Ohio.

National Fire Protection Association. May 16–19, 1949, Fairmont Hotel, San Francisco, Calif.

Ohio Welding Conference. 10th meeting. April 7–8, 1949, Ohio State University, Columbus, Ohio.

Society of Automotive Engineers. Summer meeting, June 5–10, 1949, French Lick Springs, French Lick, Ind.

Southern Machinery and Metals Exposition. 4th meeting. April 25–28, 1949, Municipal Auditorium, Atlanta, Ga.

Third International Lighting Exposition and Conference. Week of March 28, 1949, Hotel Stevens, Chicago, Ill.

General Electric Makes Annual Coffin Awards

Fifty-five employees of the General Electric Company and its affiliated companies recently received the Charles A. Coffin Award for work of outstanding merit during 1948. The awards provide recognition by the company of accomplishments of unusual merit by employees engaged in all types of work. Involved in the 55 awards are 41 separate accomplishments, some of the awards being made to several persons who are jointly credited with the achievement. Awards granted from 1948 bring to 834 the total number of individual Coffin Awards presented by the company since the program was inaugurated in 1923.

Work recognized by presentation of the awards included improved turbine production, development of a new watt-hour meter, improvement of television receivers, control systems for antisubmarine equipment, the prediction of flood crests on the Columbia River in Washington, which prevented wide flood damage at the G-E Hanford Works near Richland, Wash., and many others.

The highest number of awards, 38, went to employees of the G-E apparatus department, largest of the company's eight operating departments. The general engineering and consulting laboratory received five awards; the electronics department and the nucleonics department, two each; the appliance and merchandise department, five; and affiliated companies, eligible for the second year, three. According to the types of work in which the new winners are engaged, 23 are design or laboratory engineers, seven manufacturing supervisors, five workmen, two sales, application, and field engineers, and one employee-newspaper editor.

RMA-IRE Joint Meeting. Some of the newest technical developments in the radio-television industry will be discussed at the annual spring meeting of the RMA (Radio Manufacturers Association) engineering department and the IRE (Institute of Radio Engineers) April 25–27 at the Benjamin Franklin Hotel, Philadelphia, Pa. Technical sessions will occupy the mornings of the 3-day conference of radio engineers, and RMA and IRE committee meetings and inspection trips will occupy the afternoons. Stuart L. Bailey, president of the Institute of Radio Engineers, will speak at the spring-meeting dinner on Tuesday, April 26, at which T. A. Smith, chairman of the RMA transmitter division, will be toastmaster.

Welding Paper Prizes Offered. Six prize awards totaling $2,250 for the best papers on designing for, application of, and research in resistance welding, submitted to the American Welding Society prior to August 1, 1949, have been announced by the Resistance Welder Manufacturers Association. Top prize of $750 will be awarded for the best paper from an industrial source dealing with such topics as: redesign of a product for lower cost manufacture by resistance welding; product improvement through use of resistance welding; resistance welding research; and development of new procedures which broaden the usefulness of resistance welding. Authors of the second and third best papers in this category will be awarded prizes of $500 and $250 respectively. The author of the best paper submitted by a university instructor, student, or research fellow will receive a prize award of $300, with a $200 prize for the second best paper, from a university source, which in the opinion of the board of awards represent the greatest "original contributions to the advancement and use of resistance welding." A new $250 prize for the best paper by an undergraduate student has been added this year for the first time. Anyone in the United States and Canada is eligible to compete for these prizes, the contest judges for which will be appointed by the American Welding Society. "Industrial sources" include not only manufacturing but also consulting engineering and laboratory organizations. Copies of the simple rules governing the awards are available from the Resistance Welder Manufacturers Association, 505 Arch Street, Philadelphia 6, Pa.

High-Level Engineers Needed. Applications now are being accepted and reviewed for the position of director of research and development at the Engineer Research and Development Laboratories, The Engineer Center, Fort Belvoir, Va. The newly created position is open to individuals with at least 15 years' experience, exclusive of graduate work, ten of which should have been in research or as a research and development engineer. Five of the 15 years should have been spent as chief of a branch or department of a research and development organization with administrative and technical responsibility. Salary is $12,500 per year. Responsibilities include all matters involving the technical and scientific aspects of current research and development. Application by letter or in person should be made to the Commanding Officer, Engineer Research and Development Laboratories, The Engineer Center, Fort Belvoir, Va.

Lehigh Offers 1949-50 Fellowships. Lehigh University, Bethlehem, Pa., has announced that two DuPont Company Fellowships, one Westinghouse Fellowship, and the George Gowen Hood Fellowship, together with 35 additional fellowships and scholarships will be available for the academic year 1949–1950. Both DuPont Fellowships (one in mechanical, one in metallurgical engineering) have a stipend of $1,200, or $1,800 if the holder is married, and freedom from tuition fees. The mechanical engineering fellowship stipulates that preference will be given to an applicant well along in work toward the doctorate. The Westinghouse Fellowship is also in mechanical engineering and provides a stipend of $1,000 which may be augmented by free tuition from the university. The George Gowen Hood Fellowship, supported by the Catherwood Foundation, provides a stipend of $1,500 as well as freedom from tuition fees and applications will be received from candidates in any fields in which Lehigh University offers work for the doctorate. In the case of the specific offerings listed, the holder will devote full time to work for an advanced degree. For details write to Dean Wray H. Congdon.

PE Enters Country Life Show. The role of electricity in putting city comfort down on the farm will be demonstrated by the Philadelphia Electric Company at the National Country Life Exposition, to be held April 11, 1949, at the Commercial Museum, Philadelphia, Pa. Appliances suited to the farm wife's needs will be displayed in a model harvest kitchen showing how electric appliances have taken over every-day kitchen chores. In a utility room to one side, a modern hot-water heater, automatic laundry, dryer, and ironer will demonstrate further how a housewife's daily routine is eased through electricity. In addition to the farmhouse with its outbuildings and livestock, the Country Life Exposition will examine other aspects of rural living, and will include a village street, complete with stores carrying all sorts of merchandise.

Colorado Council Prepares Registration Law. The Colorado Engineering Council has prepared a law to be submitted to the state legislature to replace the present registration law for professional engineers and land surveyors. The proposed law follows the pattern of the model law, with minor modifications to conform with present conditions in Colorado. One difference is that the term "Practice of Engineering" includes a statement reading: "In connection with any public or private utilities, industrial buildings, structures other than buildings, machines, equipment, processes, works, or projects." The law also provides that "the certificate shall authorize the 'practice of engineers' in the branch thereof, for which the registrant has specifically qualified." A provision also is made for the certification of engineers in training.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Electrical Essay

To the Editor:

In a recent letter to the editor (*EE, Jan '49, p 90*), Doctor W. M. Leeds proposed a solution to my electrical essay, "Which Box Contains the Network?" (*EE, Dec '48, p 1141*), based on the study of the transient response of the network to the application of a special kind of voltage. Upon reading his letter, I called him on the telephone and suggested that he recheck his calculations. Within a few minutes, he called me back to confess his most extreme embarrassment, since he now found that his proposed solution was not a solution. A day or two later, he proposed to me a solution depending on temperature changes arising from heat generated in the resistors.

I have received personally several letters from members pointing out that Doctor Leeds was in error, as well as a large number of like letters received by *ELECTRICAL ENGINEERING* and forwarded to me. I agree with the editor that it would not be practical to print all of the letters received on this subject and so I wonder if these various writers will not be satisfied, if I summarize their letters by saying that they all prove in a variety of good and equivalent ways that if the elements of the network have the properties usually assumed for resistors, capacitors, and reactors in network theory, then it is not possible to distinguish between the box containing the resistor and that containing the network by any kind of electrical tests at the terminals. The members writing letters to this effect were

1. C. M. Crain and William C. Buesterkaeft, University of Texas.
2. Members of Stanford electrical engineering faculty, by W. W. Harmon.
3. Professor W. V. Lyon, Massachusetts Institute of Technology.
4. M. H. Greenblatt, P. W. Davison, and K. W. Robinson, of Radio Corporation of America.
5. E. J. Weller, Downey, Calif.
6. Ennis E. Jones, Iowa State College.
7. H. C. Turnage and H. J. Ward, Jr., Raleigh, N. C.
8. Professor C. L. Cottrell, Cornell University.
9. Egon Brenner, A. D. Bresler, and Kurt Mises, City College of New York.
10. Herbert Jared and Victor White, Tennessee Valley Authority, Knoxville, Tenn.
11. Jack Trugman, Purdue University.

It is gratifying to have this evidence that electrical network theory is being studied actively in the United States, and that there are so many able engineers thoroughly conversant with the principles. Leeds, I am sure, is happy that there are so many fellow engineers ready to come to his aid when he stumbles. I also am pleased at this evidence of wide interest in the electrical essays.

Of the foregoing writers, *2, 3, 6, 7, 9,* and *10* go further than merely saying that the method proposed by Leeds is incorrect, but also assert that the problem is impossible of solution "by purely electrical measurements at the box terminals," to quote *7*, or "within the limits of the problem as stated by Slepian," to quote *6*.

Writers *2, 4,* and *5* propose to solve the problem by somehow using the Joulean heat in the resistors. Writer *2* remarks that the instantaneous heat evolution is different in the two boxes, but suggests no means for observing this difference. Number *4* suggests accurate temperature measurements as a function of time, but states that this is not an electrical measurement at the terminals of the box. Number *5* proposes thermocouple temperature measurements at the box terminals, but apologetically calls the method roundabout.

Three other communicants believed that electric noise measurements at the terminals are "within the limits of the problem as stated by Slepian," and can give a means of distinguishing between the two boxes. F. Sutherland Macklem of Servo Corporation of America in a letter to me pointed out the different instantaneous heat generation in the two boxes, and suggested using electric noise measurements to observe this difference, but gave no further particulars. Likewise, Doctor William Altar, of Westinghouse Research Laboratories, after verifying for me at my request, that the electric noise is the same for the resistor, and the network, when all at the same temperature, proposed that the resistor and the network components be brought to different temperatures by proper excitation, and then distinguished by their electric noise. However, as yet, he has not given me the details as to how he would do this.

My own proposal, along this line, would be as follows. Send like magnitude steady currents of different frequencies through each of the boxes, holding each frequency constant long enough so that a steady state of resistor temperature is reached in the two boxes. Immediately after this heating by currents of any particular one of the frequencies, determine the electric noise at the terminals of the respective boxes. For the box containing the resistor, the intensity of the electric noise will be independent of the frequency of the heating current. For the box containing the network, however, the noise will vary with the heating current frequency.

The best solution, I believe, is that suggested to me by Doctor J. A. Hutcheson, director of Westinghouse Research Laboratories. He proposes to heat the resistors in the two boxes by passing like direct currents through them until steady temperatures are reached. Then the noise spectrum of the box containing the resistor will be of uniform amplitude over all frequencies, whereas the noise spectrum for the box containing the network will have larger amplitude at lower frequencies, and smaller amplitude at higher frequencies.

There are a number of interesting questions raised by the various letters and communications reviewed. They are, what is a problem?, when is a problem solved?, and what is a resistor? In general, a problem is a feat to be accomplished, or task to be done, subject to certain restrictions or rules of the game. Thus, a problem in engineering implies remaining within certain economic limits, or using only actually available materials or machines. For a problem in theoretical physics however, the rules of the game would be quite otherwise, and ideal elements, not existing in the every-day world, such as resistanceless fluids,or capacitance-free resistors are permissible, subject to certain other rules of the game.

The famous mathematical problems of antiquity, the trisection of the angle, the duplication of the cube, and the squaring of the circle, were the difficult and fascinating problems they were, because it was understood that they were to be accomplished by ruler and compass alone. No gentleman would use any other curve in construction than the straight line and circle, and so the ancients did not need to state their rule of the game each time any one of these problems was put. Of course, any roughneck could trisect the angle or duplicate the cube by using a cubic curve. The real problem was to do it with ruler and compass.

It was only in the last century that these famous problems were solved, and they were solved by mathematically proving that it is impossible to carry out these constructions by ruler and compass alone. Thus the solutions to these old problems are the demonstrations that there are no solutions.

The writers *2, 3, 6, 7, 9,* and *10* all solved the electrical problem under discussion here, correctly and completely, under the rules of the game as they understood them, by demonstrating that there is no solution; that is, that it is not possible to distinguish between the boxes by electrical measurements at the terminals. One of their rules of the game is that a resistor R is an element of a network for which always, $E=RI$, or the instantaneous current and voltage are strictly proportional to each other with a constant coefficient of proportionality, R. This rule of the game was established at the beginning of network theory by Ohm, Kirchhoff, and others, who were unquestionably gentlemen, and this tradition is continued by the gentlemen *2, 3, 6, 7, 9,* and *10.*

But now a new race of men has appeared, for whom a network is a maze of actual physical elements soldered to binding posts and placed in a box having dials and giving off raucous sounds. For them, a resistor is a slender black cylinder for which E equals RI only in an imperfect average kind of way. These men use amplifiers and magnify up these blemishes on Ohms law into a hideous "electric noise" which they find depends upon the temperature of their black cylinder resistors. Using this "electric noise" these men are then able to determine which box contains the network.

I would suggest, that the honors for the solution of the electrical essay discussed here be divided. One part should be awarded to Messrs. *2, 3, 6, 7, 9,* and *10* for their gentlemanly solution that there is no solution for networks having resistors satisfying Ohms law perfectly. The other part should be awarded to Doctor Hutcheson for his method of using the "electric noise" of his uncouth resistors.

J. SLEPIAN (F '27)

(Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Determining a Conjugate

To the Editor:

May I draw attention to the problem of determining the conjugate of a function?

The well-known rule that the conjugate of a complex number $(a+jb)$ is $(a-jb)$ is used widely. Its danger is that it sometimes is applied to various funcions of j, leading to incorrect or ambiguous results.

For example, one easily might write $\sqrt{(-j)}=j\sqrt{j}$ for the conjugate of $\sqrt{j}$. This would be incorrect, for $\sqrt{j}=(1+j)/\sqrt{2}$ and its conjugate is $(1-j)/\sqrt{2}$ whereas $j/j=(j-1)/\sqrt{2}$. Thus there is an ambiguity in sign and the surest way to obtain a correct expression is to reduce the original function to the form $(a+jb)$, or $e^{j\theta}$ whence the conjugate is $(a-jb)$ or $e^{-j\theta}$.

A. C. SIM (A '47)

(The British Thomson-Houston Company, Ltd., Rugby, Warwickshire, England)

NEW BOOKS

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

MESON THEORY OF NUCLEAR FORCES. By W. Pauli. Second edition. Interscience Publishers, Inc., New York, N. Y., and London, England, 1948. 69 pages, charts, tables, 8¼ by 5¼ inches, linen, $2. This volume gives students and research workers an orientation in the more recent literature on the theory of interaction of mesons with protons and neutrons and the interactions between nucleons derived from it. The second edition clarifies some consequences of the strong coupling theory. Older experiments, now rendered obsolete, have been deleted and the recent work substituted.

OUTPUT AND PRODUCTIVITY IN THE ELECTRIC AND GAS UTILITIES 1899–1942. By J. M. Gould. National Bureau of Economic Research, New York, N. Y., 1946. 195 pages, charts, tables, 9¼ by 6 inches, cloth, $3. Presents new measures of output, employment, fuel consumption, and capital investment in the electric, manufactured gas, and natural gas utilities. The changing relation of output to the use of the various resources—labor, fuel, and capital—is described, and the movement of electric and gas output and each of the input factors is traced since 1900. Retardation in rate of growth is discussed.

PRECISION MEASUREMENT METHODS AND FORMULAS. By J. Johnson. Pitman Publishing Corporation, New York, N. Y., and London, England, 1948. 181 pages, diagrams, tables, 9½ by 6 inches, linen, $3.; 16s. Bridging the gap between "school" mathematics and practical application of theory, this book on tool inspection presents actual problems and their solutions. The over-all theory behind the solution is shown clearly. Solutions are for the greater part based on setups requiring the simplest of instruments. No special ability other than knowing how to use trigonometric tables is necessary.

PRINCIPLES OF ELECTRIC AND MAGNETIC FIELDS. By W. B. Boast. Harper and Brothers, New York, N. Y., 1948. 405 pages, illustrations, diagrams, charts, tables, 9½ by 6 inches, cloth, $4.75. This textbook is designed for study by undergraduate students desiring a fundamental comprehension of electric and magnetic fields. Parts I and II provide an introduction to basic concepts, and Part III treats important supplementary aspects of the subject. The book is written in the *MKS* system of units, and a knowledge of calculus is necessary.

PRINCIPLES OF RADAR. By D. Taylor and C. H. Westcott. Macmillan Company, New York, N. Y.; University Press, Cambridge, England, 1948. 141 pages, illustrations, diagrams, charts, tables, 8½ by 5½ inches, cloth, $3.50. An exposition and survey of the principles underlying radar design. Indicates the common factors which are the basis for the many types of radar equipment developed and used during the war. Some knowledge of the fundamental principles and prewar practice of radio are needed as well as electromagnetic theory and the calculus.

INDUCTION HEATING IN RELATION TO INDUSTRIAL GAS HEATING. Project *IGR-53.* By S. L. Case and others; sponsored by American Gas Association, Committee on Industrial and Commercial Gas Research, 420 Lexington Avenue, New York, N. Y., 1948. 47 pages, illustrations, diagrams, charts, tables, 11 by 8½ inches, paper, $1. Appraising the past competitive position of gas and induction heating, this report also attempts to predict the future position. The first three sections outline the salient technological features of each type of heating and describe in some detail a few commercial examples of each type that have proved to be outstandingly successful. A fourth section presents an appraisal of metallurgical and economic factors which will be important in deciding which method is most suitable for future installations.

MECHANICS AND APPLIED HEAT. By S. H. Moorfield and H. H. Winstanley. Longmans, Green and Company, New York, N. Y.; Edward Arnold and Company, London, England. Second edition, 1948. 324 pages, diagrams, charts, tables, 7½ by 5 inches, cloth, $1.60. Written as a one-volume course in engineering science, essential principles have been stressed throughout, and descriptive matter and detailed experimental instructions omitted as far as possible. New examples from recent British examinations have been added.

METAL SPRAYING AND SPRAYED METAL. Rewritten by W. E. Ballard, third edition, based on previous editions by E. C. Rollason, T. H. Turner, and N. F. Budgen. Charles Griffin and Company, Limited, London, England; distributed in the United States by the American Metallizing Contractors Association, 773 Brownell Avenue, St. Louis 22, Mo., 1948. 362 pages, illustrations, diagrams, charts, tables, 9 by 6¼ inches, cloth, 32s; $10. in United States. Intended for the use of the operators of the process as well as the technician and scientist. New material has been added on the modern powder process, metal-spraying techniques, the preparation of surfaces, installation of plant and subsidiary apparatus, special processes, and on the properties of metal-sprayed surfaces.

PAMPHLETS

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Publications of the National Bureau of Standards. National Bureau of Standards Circular 460, listing all publications from 1901 to June 30, 1947. For sale by the Superintendent of Documents, United States Printing Office, Washington 25, D. C. Price per copy 75 cents.

ASTM Standards on Copper and Copper Alloys. Published by the American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa., listing specifications, test methods, and definitions of terms concerned with copper and copper alloys. Paper binding, $4.35; cloth binding, $5.

National Fire Protection Association Quarterly, Parts I and II. Published for members of the National Fire Protection Association, 60 Batterymarch Street, Boston, Mass. Can be received by becoming a member of the association.

Measurement of Radioactive Isotopes. National Bureau of Standards Circular 473, containing a discussion of the principles of measuring radioisotopes with illustrative examples and a chart for computing radioactive decay. Price 5 cents from the Superintendent of Documents, United States Printing Office, Washington 25, D. C.

American Standard Practice for School Lighting. Authoritative guide for school room lighting specifications and control. For sale at 50 cents a copy from the Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y.

NEMA Standards Booklets. Publication 48-135, "Standards for Series Capacitors," covering rating, manufacturing, and testing of capacitor units and assemblies. 20 pages, priced at $1.50. Publication 48-136, "Standards for Laminated Thermosetting Decorative Sheets," covering thicknesses, tolerances, grades, tests, and techniques for decoration. 24 pages, priced at 80 cents.

NAB Sample Transmitter Operating Logs and Pertinent FCC Rules and Regulations. Available upon request from the National Association of Broadcasters, 1771 N Street N. W., Washington 6, D. C.